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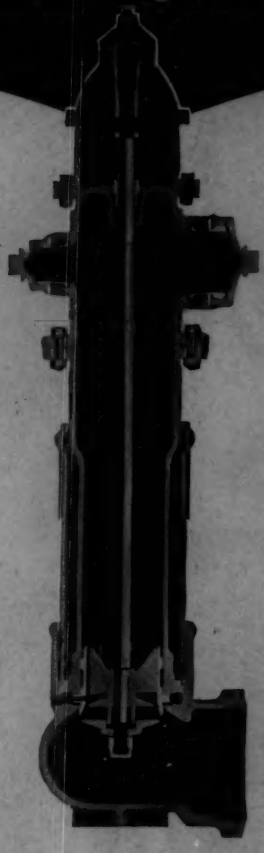

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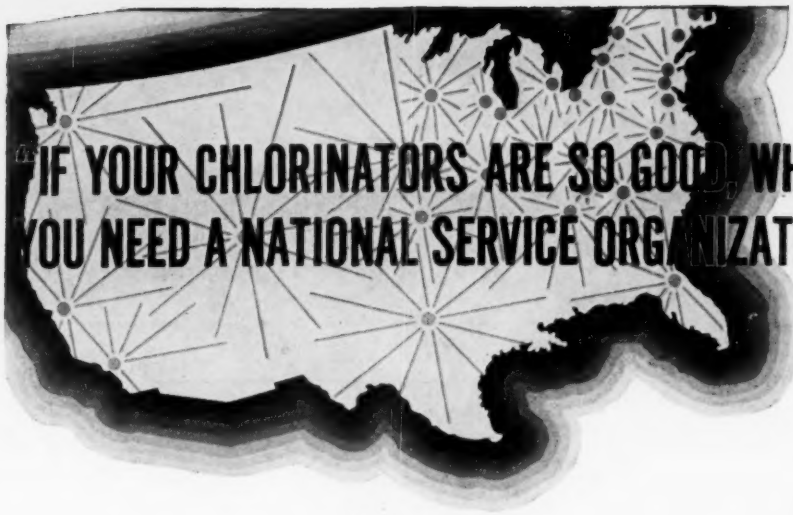

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Vol. 31 September, 1939 No. 9

Methods for Inspecting Pipe Lines

By K. H. Logan and E. A. Koenig

IT IS often necessary to estimate the condition of a pipe line or network in order to decide whether protection against corrosion is desirable, to determine whether and at what points reconditioning is needed, or as a preliminary step in the estimation of its present or future usefulness or value. Under some conditions records of leaks and reconditioning operations may furnish adequate information. Frequently, however, such records are absent or inadequate and it becomes necessary to examine parts of the line, and from results of these examinations to estimate the condition of the line as a whole or of sections thereof.

The writers have recently secured the results of detailed examinations of each joint or pipe of several hundred miles of oil pipe lines located in widely separated parts of the United States. For most of the lines these data are limited to records of the single deepest pit on each joint of pipe (usually about 20 feet in length), the number of holes in the joint, the location of the joint, and the general character of the soil surrounding it. For 25 miles of a 26-year-old 8-inch steel line the data show the deepest three pits and the estimated general condition of each joint. In estimating their condition the joints were placed in four groups, condition 1 indicating that the pipe was prac-

A paper presented on June 14, 1939 at the Atlantic City Convention by K. H. Logan, Chief, Underground Corrosion Section, National Bureau of Standards, Washington, D. C.; and by E. A. Koenig, Engineer, Magnolia Pipe Line Co., Dallas, Texas.

tically as serviceable as new pipe, while condition 4 indicated that the joints were valuable only as junk. The estimation of the condition of the line was an attempt to give qualitative consideration to the size, number and distribution of the pits and holes in each joint of pipe. This paper is a discussion of pipe line inspections in the light of the data thus obtained.

Criteria for the Condition of a Pipe Line

Before undertaking the inspection of a line the inspector should decide what observations are necessary for his ultimate objective, since several kinds of observations might be made, not all of which would be equally informative. The character of the observations should depend somewhat on the use that is to be made of the data and the service expected of the line. Thus the loss of metal by a section of pipe might be of primary importance. This can be estimated under favorable conditions from determinations of the change in the electrical resistance of sections of the line. If the line is to be reconditioned by spot welding the number of pits to be welded is the information most needed. Under other conditions the depths of the deepest pits may be of greater interest. It is not possible therefore to state an objective which should govern all inspections.

In order to bring out possible correlations between various measurements, a 25-mile line was first divided into 1-mile sections. For each joint of pipe within each section the number of leaks, the averaged depths of the deepest three pits, the depth of the single deepest pit, and the condition of the joint were tabulated and averaged for each section. The correlations between the other averages and the average condition of the joints are shown in fig. 1. Although these data exhibit a high dispersion it is evident that similar results are obtainable by these various types of measurement and inspection. Which of these types of observations is most informative or whether some other type should be used must be left to the one responsible for the inspections. For the purpose of illustrating certain factors related to inspections and some methods of handling and interpreting inspection data, the authors have used the deepest pit on each joint of pipe. In many cases the ideas and methods are applicable to other types of inspection data.

When an engineer decides to inspect a pipe line at certain points for the purpose of determining the condition of the line as a whole,

certain questions require his consideration regardless of the character of the observations he proposes to make. Some of these are so interrelated that one cannot be fully discussed until some of the related points are at least partly understood. On this account it will be necessary to defer the completion of the discussion of some of the topics until other topics have been presented.

Amount of Pipe to Uncover at One Inspection Point

Underground corrosion, which usually controls the condition of pipe lines, is so varied that if a small area of the pipe's surface is

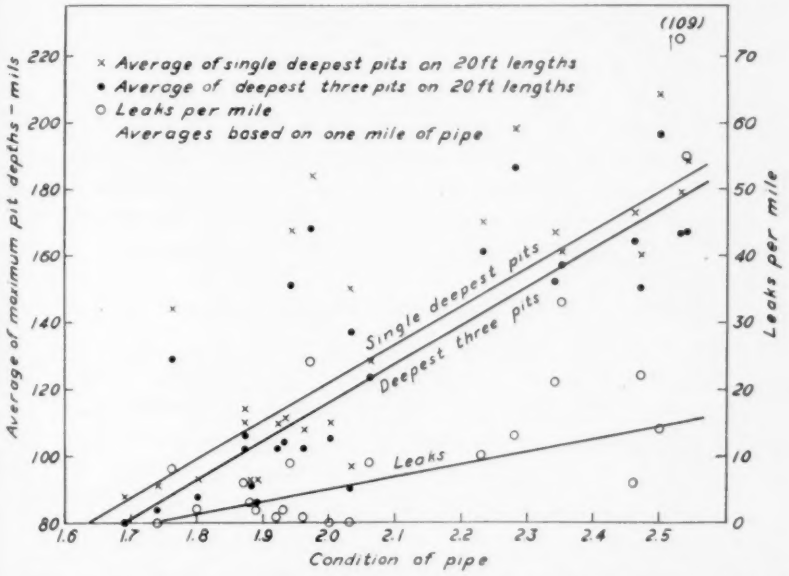

FIG. 1. Relation between leaks, maximum pit depths and condition as determined by visual inspection of 1-mile sections of an 8-inch steel pipe line.

examined it is probable that the data obtained will differ from the results of another similar examination. The estimation of the true condition of the line, therefore, requires a large number of such examinations. If larger areas are chosen for the unit for inspection, the data will probably have a narrower range. If the deepest pit on the unit area is the datum observed, it will be found that the average of the deepest pits on a number of small areas will be less than the corresponding average for larger areas. This is illustrated by the lower curve in fig. 2 in which the linear feet of pipe inspected

are indicated at the bottom of the figure. This curve is based on data from a 9-year-old 12-inch steel line exposed to a heavy clay soil and it was plotted on the assumption that an inspector started at 48 points along the line and uncovered 1 foot of pipe on which the deepest pit was measured. The trench was then extended 1 foot and the deepest pit on each 2-foot length determined. Similarly, the deepest pits corresponding to greater lengths up to 20 feet were measured. It will be noticed that as the unit for inspection increased the average of the deepest pits increased. It might be thought that by choosing some greater length for the unit for in-

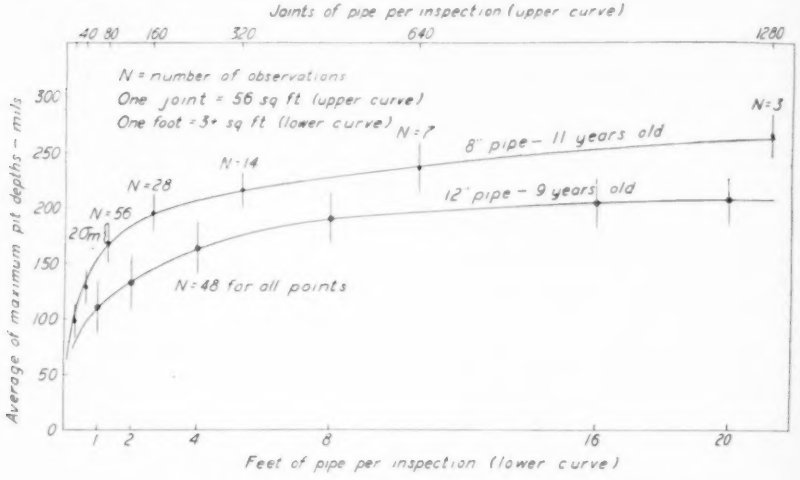

FIG. 2. Relation of maximum pit depth to area inspected

spection an area might be found such that the choice of a still larger area would not result in larger values when the maximum pit depths are averaged. The upper curve in fig. 2 which is based on the inspection of 16 miles of 11-year old 8-inch steel pipe exposed to a sandy loam soil, shows that this is not the case. Similar studies on a number of pipe lines under a wide range of soil conditions show no exception to this relation. The relation between the average of the depths of the maximum pits and the area from which it was chosen has been expressed mathematically by several investigators, but for the present discussion it is sufficient to say that the average observed maximum pit depth will depend to some extent on the area

of the pipe from which the deepest pit is chosen and therefore this area must be noted if the data are to be correctly interpreted. It will be shown later that the data show less dispersion as the unit area inspected is increased, and that the average of the maximum pit depths to be expected on an area of moderate size can be estimated from the average of the maximum pit depths on a somewhat smaller area. It follows that, within limits, the inspector may select any area for his unit of inspection which local conditions dictate if he measures the maximum pit depths on at least two adjacent known areas.

Several pipe line engineers have advocated exposing 4 feet of pipe and measuring the depth of the deepest pit on each 1-foot length. The measurement of the deepest pits on four adjacent unit areas has an advantage which will be mentioned later. Many engineers prefer to expose a joint of pipe. Subdivision of this length could of course give the data the advantages of the measurements on four 1-foot sections, but this practice is not usually followed. The effect of the area on inspection data other than maximum pit depths has not been extensively investigated to the authors' knowledge.

Number, Spacing and Location of Inspection Points

The fundamental principle in inspecting pipe lines at a few points in order to estimate the condition of the entire line is that the data so obtained shall be representative of the various conditions along the line. The rules for sampling materials are generally applicable.

Random Inspections

Occasionally an attempt is made to determine the condition of a pipe line or system by examining the pipe at points where it happens to be exposed for connections, repairs or other purposes. These inspections may be supplemented by others at points where conditions appear to be different. A sufficiently large number of such inspections might yield representative data but probably many more would be required than for inspections chosen more systematically.

Equally Spaced Inspections

Gill (1) in an excellent discussion of pipe line inspection, maintained that adequate data can be obtained only by inspecting a line at equally spaced intervals. The data obtained by this commonly

used method may be treated by statistical methods which will indicate the adequacy of the data.

Number of inspections: Table 1 illustrates the relation of the averages for the single deepest pit on a joint of pipe to the number of inspections and to the interval between equally spaced inspection points.

The data in the first line of the table are the results of measurements of the depths of the deepest pits on each 20-foot section of the line and therefore represent the actual condition of the line with respect to the average of the maximum pit depths. The average for the deepest pits may vary somewhat with the number of inspections made. However, the standard error of the estimated average increases as the number of inspections is decreased. For these data

TABLE 1

Effect of the number of inspection points on the average of the observed maximum pit depths on 20-foot sections of a 25-mile 8-inch line

DISTANCE BETWEEN INSPECTION POINTS	NUMBER OF INSPECTIONS	AVERAGE FOR SINGLE DEEPEST PITS ON 20 FEET	STANDARD DEVIATION OF MAXIMUM PIT DEPTHS	STANDARD ERROR OF THE AVERAGE
feet		*mils*	*mils*	*mils*
20	6384	139	65	0.8
660	200	137	63	4.5
1320	100	143	70	7
2640	50	143	70	10
5280	25	138	66	13

the true average lies within the estimated averages plus or minus their standard error regardless of the number of inspections. Statistical considerations show that the probability is about 0.95 that the average obtainable by the complete inspection will be within the estimated average plus or minus twice its standard error. It will also be noted that the standard deviation of the data, which is an indication of their dispersion, is nearly the same for all inspection frequencies, i.e., for the line under consideration the 25 inspections one mile apart approximately covered the range of conditions on the line. The relation between the number of inspections and the precision of the averages of pit depth data will be illustrated for other pipe lines by figures to be presented in the next section of this paper.

Influence of starting point: Since the conditions of two short sections of a line which are only a few feet apart may be very different,

it has been thought by some that the location of the starting point for equally spaced observations might affect the averages of the inspection data. This question was investigated by means of pit depth measurements on three widely separated and quite different pipe lines. A comparison of the results for different numbers of inspections, different spacing of inspection points, and for different starting points, is illustrated by fig. 3.

Each of the first eight columns in fig. 3 represents the average of measurements of the depth of the deepest pit on each of 25 joints of 8-inch pipe (20 feet long). The inspections were made at 1-mile intervals. The different columns represent the data for 8 starting

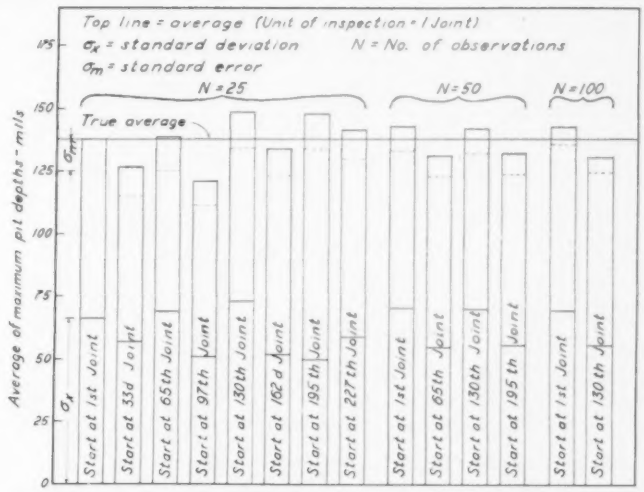
Top line = average (Unit of inspection = 1 Joint)
σ_x = standard deviation
N = No. of observations
σ_m = standard error
N=25
N=50
N=100
True average
Average of maximum pit depths - mils
Start at 1st Joint
Start at 33d Joint
Start at 65th Joint
Start at 97th Joint
Start at 130th Joint
Start at 162 d Joint
Start at 195th Joint
Start at 227th Joint
Start at 1st Joint
Start at 65th Joint
Start at 130th Joint
Start at 195 th Joint
Start at 1st Joint
Start at 130 th Joint

FIG. 3. Comparison of maximum pit depths for different starting points of equally spaced observations. Inspection intervals $\frac{1}{4}$, $\frac{1}{2}$, and 1 mile.

points separated by one-eighth mile intervals. The next four columns show the results of 4 sets of 50 inspections of the same line, the inspections being $\frac{1}{2}$ mile apart. The last two columns show the results of inspecting the line at $\frac{1}{4}$-mile intervals, using 2 starting points. Although there are slight apparent differences in the averages resulting from different starting points, no two averages differ by more than the sums of their standard errors. The probability of there being a real difference in the averages is therefore small.

The horizontal line crossing the figure indicates the average of the depth of the deepest pit on each of 6,403 lengths of 20-foot pipe. It will be seen that in all cases the estimated averages of the deepest

pits differed from the true average by less than twice their standard errors. This is, of course, what might have been predicted from a knowledge of statistical methods, and is another way of showing that the starting point had no real effect on the average.

Figure 4 shows the results of measuring the deepest pit at space intervals of 1, 2, 3, and 5 miles, using eight starting points. The data are derived from measurements of the deepest pit on each 20-foot length of a pipe line approximately 200 miles long. Although the deepest pits on 72 per cent of the joints in the line were less than 40 mils in depth, many joints were punctured. The dispersion of

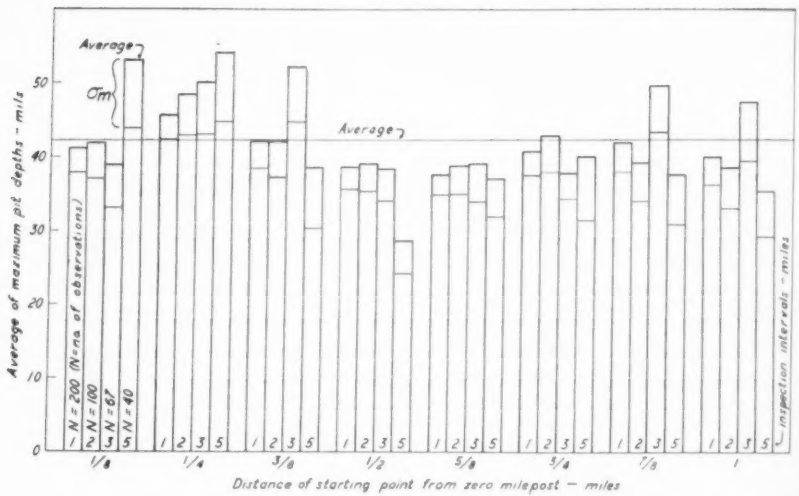

FIG. 4. Comparison of maximum pit depths for different starting points of equally spaced observations. Inspection intervals 1, 2, 3, and 5 miles.

the data was so great that the standard deviation for several sets of measurements exceeded the values of the averages and to avoid confusion the standard deviations of the data have not been shown in the figure. For the inspections at 5-mile intervals starting at the half-mile point, the estimated average differs from the true average by more than twice the standard error of the average, but this is to be expected for about one out of 20 averages. Figure 4 in addition to showing that the starting point has no real effect on the data, shows that the reliability of the average as indicated by the standard error decreases as the number of inspections is decreased. Figure 5 also illustrates the unimportance of the starting

point and in addition shows that the dispersion of the data as indicated by their standard deviation decreases when the area from which the deepest pit is selected increased.

Inspections Based on Soil Characteristics

Denison (2, 3) and Ewing (4, 5) have shown that the corrosion of pipe lines as measured by leaks and replacements can be related to the types of soil which the lines traverse. This is illustrated by table 2 which is abstracted from a more complete table in one of the papers (3) just referred to. Figure 6 illustrates the difference in

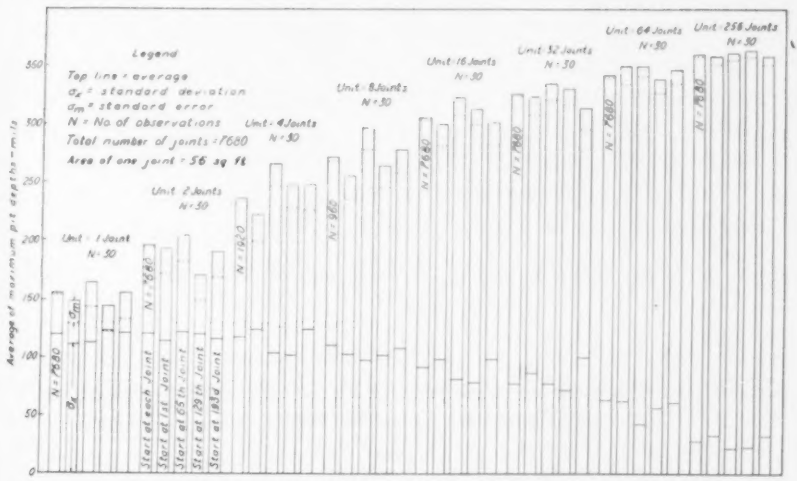
Legend
Top line = average
σ_x = standard deviation
σ_m = standard error
N = No. of observations
Total number of joints = 7680
Area of one joint = 56 sq ft
Unit - 1 Joint N=30
Unit - 2 Joints N=30
Unit - 4 Joints N=30
Unit - 8 Joints N=30
Unit - 16 Joints N=30
Unit - 32 Joints N=30
Unit - 64 Joints N=30
Unit - 256 Joints N=30
Average of maximum pit depths—mils
Start at each Joint
Start at 1st Joint
Start at 65th Joint
Start at 129th Joint
Start at 193d Joint

FIG. 5. Relation of starting point and area inspected at each point of inspection to the average of maximum pit depth—30-mile line.

corrosiveness of soil types as indicated by the depths of maximum pits. Since the corrosion of a pipe appears to be characteristic of the type of soil to which the pipe is exposed and since a large percentage of a pipe line may be exposed to the same soil type it seems probable that under favorable circumstances the process of estimating the condition of a long pipe line might be shortened by first determining the amount of line in each kind of soil traversed and then determining the average condition of the line exposed to each of the several kinds of soil. This procedure would also have the advantage of locating the sections of line which differed in corrosiveness, an advantage of considerable importance if the line is to be protected or reconditioned. Obviously, if the line traversing one kind of soil

has been protected by two or more coatings differing in effectiveness the coatings will so modify the corrosion that the soil type must be subdivided according to the extent of the coatings.

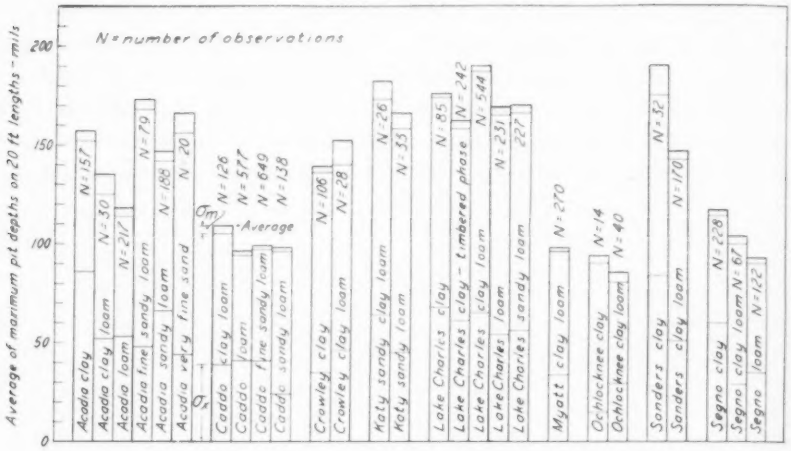

FIG. 6. Averages of the deepest pit on each joint of pipe in different types of soils

TABLE 2

Corrosiveness of certain soil types with respect to a pipe line system having an average age of 33 years

SOIL TYPE	AV. NO. OF LEAKS PER 10,000 FT.	% OF LINE RECONDITIONED
Trumbull clay loam	20.2	44.1
Nappanee clay loam	15.9	54.8
Chagrin silt loam & fine sandy loam	13.6	21.6
Mahoning silt loam	12.8	19.8
Holly clay loam	11.7	22.6
Volusia silt loam	8.1	19.0
Wooster loam	4.2	4.6
Clyde clay loam	2.5	5.3

A difficulty involved in the use of soil types in the inspection of lines is that usually to get a reliable average of the depths of the deepest pits in a soil type at least 20 observations must be made, and within a few miles many soil types may be encountered. Thus in traversing a distance of approximately 25 miles one pipe line en-

countered 38 soil types, several of these types occurring at several places along the line. If 25 observations were made for each soil type 950 excavations or an average of 38 per mile, or 1 every 140 feet, would have been necessary. Certain of the soils encountered may affect only a few hundred feet of the line and it may not be worth while to determine their corrosiveness. Neglecting these unimportant soil sections and combining the soil types that are similar with respect to their properties which affect corrosion would of course considerably reduce the number of observations.

Methods of Presenting Inspection Data

Having inspected a pipe line at a considerable number of places, the inspector faces the problem of presenting the data most effectively. One of the first steps might be the computation of the average of the observed pit depths or other observations, their standard deviation, and the standard error of the average. This will give some information as to the dispersion and dependability of the data and form a basis for deciding whether more data are needed. Because of the wide dispersion of most corrosion data an average alone will convey but little information as to the condition of the various parts of the line which may differ greatly.

Standard errors and standard deviations have been mentioned on several occasions. If the data have a normal distribution these characteristics of the sample have definite meanings. If the distribution is skewed their significance is less definite. Although data on maximum pit depths usually have skewed distributions the standard errors of the averages have been found to have approximately the same significance with respect to probability predictions as the standard errors of the average of normally distributed data, i.e., the ordinary probability tables may be used in estimating the reliability of the averages. However, because of the particular type of skewness of these data, application of these tables to the estimation of the number of pits that exceed the average of the maximum pit depths by n times the standard deviation of the data results in too low an estimate. This is illustrated by fig. 7, which represents the results of 8 inspections of a 200-mile line at 1-mile intervals starting at points $\frac{1}{8}$ mile apart.

Each of the 50,000 joints of pipe in the line was examined and the deepest pit on each was measured if it was over 40 mils in depth. The average of the pit depths is shown by the vertical line crossing

the figure. The estimated averages of the depths of the deepest pits and twice their standard errors are also shown for each of the series of inspections. At the right of each estimated average 2.8 times its standard deviation is shown, and the depths of the pits exceeding the average by more than 2.8 times the standard deviation are indicated by crosses. If the data had a normal distribution the probability of the occurrence of a pit deeper than the average plus 2.8 times its standard deviation would be about 1 in 200, or, on the average, only one cross would be expected for each series of observations plotted.

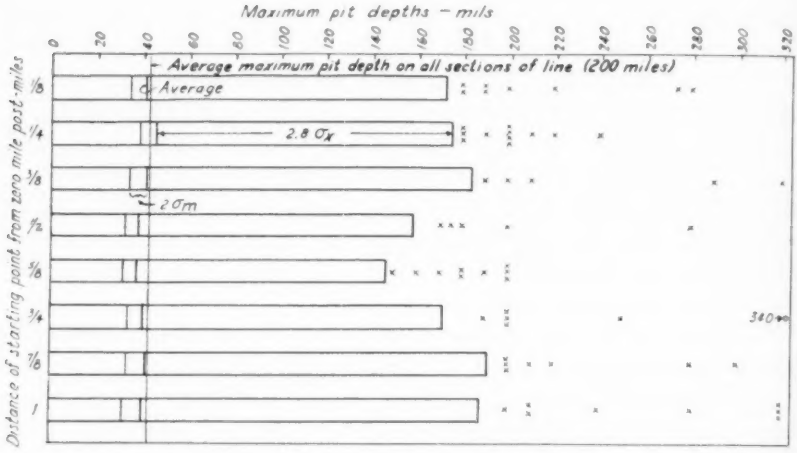

FIG. 7. Dispersion of pit depths on a 200-mile pipe line

Since in 8 trials the number of pits exceeding the average of the maximums by 2.8 times the standard deviation ranges from 5 to 9, it is evident that the probability tables for normal data are not applicable for estimating the frequency of occurrence of pits on pipe lines.

An effective way of presenting the data is by means of a histogram or frequency polygon as illustrated in fig. 8. The solid line represents the results of 6,384 determinations of the deepest pit on 20-foot lengths of pipe. The large number of data so obtained makes it possible to use a pit-depth interval of 10 mils. The broken line represents maximum pit depth measurements on the same length of pipe taken at intervals of one mile. The limited amount of data so obtained makes it desirable to use pit depth intervals of 40 mils in plotting the data. The two histograms are roughly similar. This

shows that for this line one inspection per mile was sufficient to yield a roughly correct picture of the distribution of the pits with respect to their depths. The data from which the histogram was constructed may be combined for the construction of a cumulative frequency distribution or ogive which will show directly the number or percentage of the observations exceeding any value. For some purposes, this is handier than the histogram.

Superimposed on the histograms in fig. 8 are a smooth distribution curve and lines indicating the average of all the pit depths and the

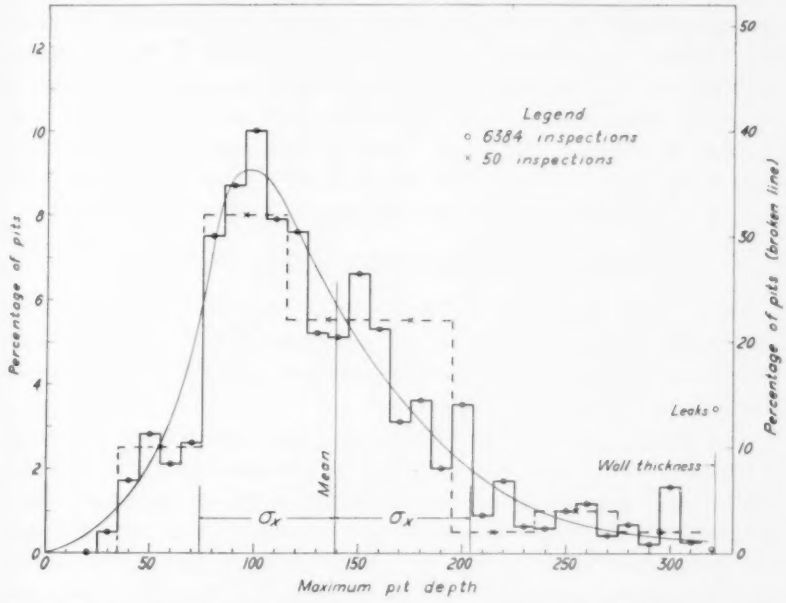

FIG. 8. Frequency histogram for pit depth measurements on a 25-mile pipe line

standard deviation of the data. These lines afford additional information to one familiar with statistical methods.

If the pipe line is to be reconditioned the location of the seriously corroded sections is needed. If the inspection interval is not too great these sections may be located roughly by plotting on profile paper the pit depths or other observations against the identification numbers of the inspection points. The extent of badly corroded areas is rendered much more certain if the inspections have been made on the basis of soil types as suggested in an earlier part of the

paper, although there may be a wide range in maximum pit depths on different sections of pipe in a single type of soil as was shown by the standard deviations in fig. 6.

Data of the character described in this section furnish a fairly definite picture of the condition of the line at the time of its examination. It is possible with some additional data to estimate other things of interest.

It has already been shown that the average of the deepest pits on a number of equal areas increases as the areas increase. If a sufficient number of pits are measured on at least 2 areas at each point of inspection it is possible to employ equations developed by Scott (6), Ewing (7), and Rhodes (8) in the prediction of the pit depths on larger sections of pipe than those actually examined. All of the equations are empirical and although they are based on a large number of observations, their accuracy and applicability to other pipe lines have not been fully established. They are at least very suggestive of what might be found by more extensive inspections.

Interpretation of Data on Maximum Pit Depths

Usually the objective of a pipe line inspection is related to the future rather than the present. The data resulting from inspections, therefore, require interpretation as to their significance with respect to the future condition of the line.

The prediction of future pit depths, leaks, and probably of other phenomena resulting from corrosion is a somewhat difficult undertaking, and the results of such predictions are of uncertain value. A considerable amount of information concerning corrosion phenomena has been collected and is worthy of consideration as a supplement to the judgment and experience of the expert on pipe line conditions. Several investigators have developed empirical equations for the relation which they have found between pit depths and period of exposure on pipes of different ages. A number of these equations are given in one of the papers (9) previously referred to. All of the equations involve the use of a factor which purports to show how the loss of metal or the depth of the pits increases with time. Since in most cases it is not possible to determine this relation by substituting in the equation the pit depths or other corrosion data observed after different periods of time, it is usually necessary to determine the constants of the equations indirectly. There are two bases for doing this. Soil types have been found to have characteristic corrosion-

time factors (10). If the line in question lies in soils whose factors have previously been determined, or in similar soils, the corrosion-time equation may be solved. It has also been found that the corrosion-time factor is roughly a function of the aeration of the soil. The authors of the paper referred to therefore proposed that soils be divided into four groups with respect to aeration, and suggested a factor to be used with each group in the absence of more accurate information. The fact that there is a relation between the soil type and the corrosion-time constant is an additional reason for the determination of the soil types as a part of a pipe line inspection

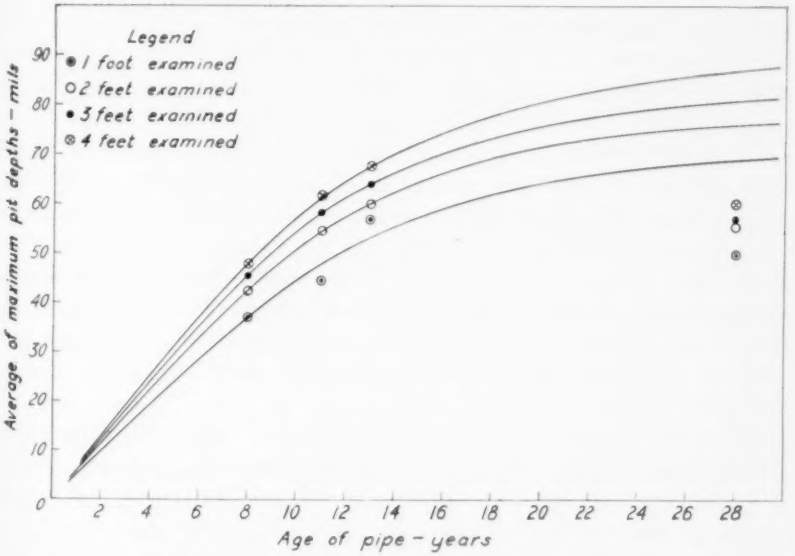

FIG. 9. Pit depths on parallel lines differing in age

program. Since corrosion rates change differently in different soils, and since most lines traverse a number of soils, the relations between the conditions of different parts of the line may not remain constant, and any prediction of the future condition of a line should therefore be based on the consideration of the line by sections.

It might be thought that the progress of corrosion could be determined by examining lines of different ages exposed to the same soil. That there may be a fallacy in this reasoning is illustrated by fig. 9 plotted from data furnished by the Gulf Oil Corporation.

Figure 9 shows the results of measurements of the deepest pits on

1, 2, 3 and 4-foot sections of 4 parallel interconnected 8-inch lines at 1-mile intervals. The lines were 52 miles long, uncoated, and on the average, laid at nearly the same depths. The data for the three newer lines are consistent and indicate a decrease in the rate of corrosion as the lines become older, but the average pit depths on the sections of the 28-year old line were less than those on corresponding sections of the 13-year old line. Sufficient data are not available to justify a positive statement as to why the oldest line shows the lowest rate of corrosion. There is, however, some evidence (11) that when a new pipe line is laid parallel and connected to an older one the new one corrodes at a more rapid rate because of a difference of potential between them which makes the new line anodic. The data for the 13- and 28-year old lines show that the corrosion record of one line may not be a safe basis for the prediction of the progress of corrosion of an adjacent line exposed to apparently similar conditions.

If an equation for the pit depth-area relation is combined with one representing the effect of time on pit depths, the resulting equation will indicate the maximum pit depth on any chosen area or length of pipe at any selected time, providing the values of the constants in the equations can be determined. The reliability of the indications depends on the accuracy of the equation and the dependability of the data. It is very desirable, therefore, that whenever possible the standard errors of the results be calculated as in one of the papers (7) referred to.

It should be remembered that the equations only purport to show the average of a number of observations sufficiently large to be representative. No equation should be expected to predict the pit depth or other corrosion phenomenon at any single point and the fact that the use of an equation results in an estimated value far different from a single observed value is not a strong indication that the equation is incorrect.

Summary

Analyses of a large amount of data on pipe lines differing in size, length, location and conditions of exposure illustrate certain corrosion phenomena and show how data obtained by inspecting a relatively small part of a pipe line may correctly indicate the condition of the entire line. Methods of treating data to get the most out of them have been discussed. The data may also be of interest as examples of the corrosion which sometimes affects pipe lines. Obviously they

should not be made a basis for conclusions as to the seriousness of corrosion on pipe lines in general.

The simplest way to determine the condition of a pipe line is to inspect it at equally spaced intervals. The number of inspections will depend on the required precision of the results. The precision of the results of a number of inspections can be determined by statistical methods.

If a representative number of observations are made, starting the observations at different points on the line does not produce differences in the results that are greater than the uncertainties indicated by the standard errors of the results.

A cumulative frequency distribution curve will show how many pits exceed any specified depth.

If sufficient data are plotted on profile paper the sections of the line where corrosion is worst may be roughly located.

If a long pipe line is to be examined it may prove economical to locate the boundaries of the soils traversed by the line and then to determine the corrosion associated with each soil type. This procedure is especially helpful when the boundaries of the seriously corroded sections are desired.

If maximum pit depths are the criterion used for determining the condition of a pipe line, the average of the depths observed will increase with the area from which each maximum is chosen.

Empirical equations are available which express the relation of the maximum pit depth to the size of the area considered in determining each maximum and to the duration of the exposure of the pipe to the soil. These equations are intended for use with a large number of observations and indicate only the average result to be expected. They are not applicable to the estimation of individual pit depths.

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Discussion by *Elson T. Killam.* * The data presented in the paper by Messrs. Logan and Koenig, represent an unusually comprehensive compilation of information and a graphic arrangement thereof which should provide a valuable reference as a guide to undertaking similar work. Although these data have been derived from inspection of the exterior of oil lines, it seems likely that the conclusions in general may be found applicable to water lines.

In the case of certain pipe lines subject to both external and internal corrosion, as with lines in corrosive soil carrying aggressive water, the relation between pit depth and prevalence of leaks would, of course, be radically affected by the chance occurrence of pits coinciding on both the interior and exterior of the pipe wall. Table 1 is believed to be particularly significant in illustrating that the average of the deepest pits in 25 miles of pipe was essentially the same (140 mils ±) when determined by inspection intervals varying from 20 feet to 1 mile.

These data indicate that valuable results may be attained under favorable conditions with a reasonable scope of inspection. This fact is of particular importance to application of inspection methods to water supply lines, where the areas which may feasibly be uncovered are limited due to greater depth, greater diameter, more local obstacles to excavation and similar factors in the case of water lines as compared with oil lines.

The results of the painstaking study of data as presented would seem to indicate that a careful evaluation of essential data, thorough analysis of salient variations of controlling conditions along the route, and the application of judgment based on a wide first-hand experi-

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ence with this particular type of work, would have an important effect on cost and accuracy of inspection. It follows that with adequate emphasis on the foregoing preliminary steps, the actual inspection work may be substantially curtailed.

Table 2, illustrating the relative corrosiveness of various types of soil, deserves particular emphasis. With eight different soils, the number of leaks per 10,000 feet varied from 20.2 to 2.5; and the per cent of line reconditioned varied from 44 per cent to 5.3 per cent for the respective soils.

This marked difference in results illustrates the importance of preliminary work in soil classification—and the inevitable increase in scope of inspection work made essential by diversified soils.

Figure 8, showing that one inspection per mile was adequate to yield an approximate measure of pit distribution with respect to depths, is deserving of especial emphasis.

Discussion by *E. B. Black*.* Because I have not had the opportunity to study and analyze the data presented, as such data has to be studied and analyzed before the discussion can be of much value, my remarks will have to be limited to general theory and its practical application.

It is my opinion that the National Bureau of Standards through Mr. Logan, is presenting engineers and operators with the most valuable data available on pipe line corrosion. Perhaps my interest is intensified because the more recent studies of the Bureau have considered and developed the data on corrosion in the order my experience teaches me is necessary.

The depreciation existing in a pipe line at a given date, and the rate at which that depreciation will accrue in the future, are matters of fundamental importance both in the operation of a utility and in determining the value of the property on which rates must be based. Unfortunately there may be considerable cost involved in investigating and determining depreciation in a utility, and Mr. Logan has outlined a number of plans which will vary as to cost and from which the investigator may take his choice, depending on the accuracy he wishes to obtain.

It seems to me that none of the formulae now offered, "by which pit depths can be predicted if the characteristics of the soil with respect to corrosion can be determined," are of any great value.

* Consulting Engineer, Kansas City, Missouri.

In the first place the amount and rate of corrosion depend largely on the variation in the metal of which the pipe is manufactured. Data concerning this are included in bulletins published by the Bureau of Standards. Some pitting is not dependent on the soil surrounding the pipe. Protective coatings of earth, rust, or scale, may confine the pitting action to the pipe wall, *and the action may be accelerated, instead of being retarded.*

In my opinion one of the great defects in the practical determination of depreciation on a given property by the use of a formula, is the application of soil characteristics determined in Missouri, to "about the same character of soil" on pipe lines in Texas, Oklahoma, Kansas, Nebraska, or vice versa. Depreciation is something that requires intensive study of the specific property under consideration.

Formulae, unfortunately perhaps, are usually developed by the use of a mass of field or laboratory data which require the author of the formula to choose the points through which he draws his curve, and any engineer or operator using any formula should be conversant with the probable error involved, for it may affect his conclusions.

Perhaps it will be well to direct attention to the fact that while Mr. Logan's work has involved both steel and cast-iron pipe, the paper presented here deals entirely with steel pipe, and the problem of water distribution engineers is largely with cast-iron pipe. The depreciation of cast-iron pipe, from pitting for example, is entirely different from that of steel pipe. Pits seldom occur in cast-iron pipe. Electrolysis removes the metalic iron from cast-iron pipe, but leaves the pipe in its original form and thickness. The pipe usually remains in service, both in gas and water systems, until the affected area fails from internal or external impact or pressure. A pit on steel pipe, caused by electrolysis, is a different matter.

Mr. Logan's years of experience on this matter of corrosion are available to engineers and operators through the bulletins of the National Bureau of Standards, and it seems to me that this Association would be taking a forward step if it would cooperate with the Bureau to the extent that the Bureau would extend its studies on depreciation of *cast-iron pipe in service* to the same degree that its studies cover steel pipe.

Progress Report

American Research Committee on Grounding

SINCE the American Research Committee on Grounding was organized in 1936 its Technical Sub-committee has made about 40 field investigations in situations where troubles of various kinds had developed and where it was believed that stray alternating current was a factor in the trouble. The type of complaints received and the number of each kind investigated are as follows:

TYPE OF COMPLAINT	NUMBER OF CASES
Sediment in water	4
Discoloration of water or staining of fixtures	16
Corrosion of boiler tubes	3
Corrosion of house piping	7
Electric sparking	2
Electric shock	2
Taste and/or odor	5
Fire	1

In addition to these complaint cases, field and laboratory studies of a number of other phases of the grounding problem have also been carried on. These comprised:

a. Mathematical study of leakage currents within water pipes near electrical connections and at joints.

b. Studies of fundamental corrosion and polarization effects with and without superimposed alternating currents, including simulated pipe tests and the design, construction and use of a direct current amplifier-oscillograph for photographically recording these potentials.

Submitted on June 12, 1939 at the Atlantic City Convention by C. F. Meyerherm, President and Engineer, Albert F. Ganz, Inc., 511 Fifth Ave., New York, N. Y., and Secretary of the American Research Committee on Grounding. Chairman of the Committee is H. S. Warren, 420 Lexington Ave., New York, N. Y.

c. Inspection and tests of a large building installation where an attempt had been made to keep electrical ground connections off the pipes.
d. Measurements of alternating current on lead jointed and non-metallic jointed cast-iron street water mains.
e. Measurements of the resistance to earth of individual water service pipes and of the secondary neutral where the water mains are of transite pipe.
f. Study of the effect of small variations in the composition of copper tubing on the corrosion characteristics.

Two annual progress reports have been issued and the third one is issued herewith. No definite conclusions have been drawn from the work to date, and the Committee plans to continue along the same general lines, but including a series of tests on a laboratory installation of pipes with current on some pipes and no current on others.

The question whether alternating current on water pipes does or does not have a detrimental effect on the pipes or the water within them is still undecided and while the Committee has no positive proof that such harmful effects do occur, this lack of evidence does not prove that the action cannot take place.

The uncertainty concerning this major phase of the Committee's work arises primarily from the insufficiency of cases and the complications introduced into each particular case, by local factors the effect of which is not completely determinable. For this reason the program for the future contemplates more field work and more emphasis on laboratory studies of fundamental corrosion and polarization effects, as well as tests on special pipes where some at least of the local factors can be controlled or eliminated. The preliminary developments for these laboratory studies have now been completed, and with the newly designed apparatus, and the general refinement of test procedure, it is hoped that the coming year will show considerably more progress than previous ones.

Taken as whole, the Committee's work to date has been exceedingly interesting and instructive to all who participated, and it will unquestionably lead to some very constructive suggestions in connection with grounding as well as piping practices. The cooperation between the various interests has been most cordial and effective. The Committee has also been in contact with The Institution of Civil Engineers' Research Committee's Sub-Committee on Earthing to Metal Water Pipes and Water Mains which is making a similar study of grounding in Great Britain and it is of interest to note that

this British Committee has not made any more progress than we have in America. The same difficulties have been experienced in both studies and the British group has prepared an elaborate research program which will probably get under way shortly. We have also had a number of meetings with an Australian group of electrical engineers who recently visited the United States to study grounding practices and problems here with particular reference to transite water main installations.

In order to give some idea of the type of information which the American Research Committee on Grounding has obtained so far the following brief summary will be of interest.

The Committee has verified the fact that even under normal operating conditions ground connections from the neutral conductor of electric light or power systems to water pipes regularly carry substantial alternating current ranging from 25 to 75 per cent of the house load. This current interchange usually takes place over the water service pipe between the point of attachment of the ground wire and the street main and over sections of the street main. In a number of cases, however, the Committee has found substantial stray alternating currents on house pipes inside of buildings because the house conduits, cable armor, metal lath, and water pipes afforded a better electrical path than the ground connection.

The Committee has found a number of cases of electric shock, and one case of a serious fire resulting from radio ground connections. It has found that the ground clamp or ground connection attachment problem requires drastic review both from the electrical as well as the water works viewpoint. It has also found that with a cement-asbestos water main system, a reasonably low impedance ground for the electrical distribution system will be obtained if there are numerous water service pipe grounds on each transformer circuit. With cement-asbestos mains there is only a very small current interchange over the water services and no current on the main itself.

The Committee has found cases of blue or green staining where there was current on the water service pipe but no current on the house pipes. In some of these cases the trouble diminished or disappeared after the water supply was treated with lime. It has also found several cases of similar staining where there was substantial current on copper house pipes but the staining persisted after the current on the pipes was entirely eliminated. There is also some evidence to indicate that blue or green stain troubles with copper or brass house pipes may be somwhat accentuated if the supply is

from a dead-end main with little or no circulation. The data on the staining question are not very conclusive, however, and more extensive investigations of this nature will have to be carried out before reliable conclusions can be made.

In connection with the wide differences in the amount of blue or green stain or in the copper content of the water observed with copper tubing connected to the same water supply, the Committee has just recently uncovered evidence which seems to indicate that these differences may be caused by variations in composition of the copper permissible within the present manufacturing specification limits. These variations amount to only a few hundredths of one per cent but if they affect normal corrosion where there is no stray current involved, they may be still more of a factor where current is present.

The Committee has found that while Leadite, Hydrotite, or similar non-metallic jointing compounds substantially increase the resistance or impedance of the electrical path along the water main, there is nevertheless substantial alternating current interchange over mains laid with non-metallic jointing compounds especially after these mains have been in service a number of years.

In the Committee's contemplated program involving the amplification and extension of the laboratory work with regard to fundamental corrosion and polarization, and the experiments with an actual set of test pipes, the water works industry can and should take an active part. The Committee's present facilities have developed methods of testing and elaborate equipment for this work but these agencies cannot properly do more than carry out the preliminary and exploratory phases of the various investigations. A considerable amount of detailed check testing under practical conditions is needed. This is primarily a water works job, and the Association should be prepared to undertake the assignment. Furthermore, in connection with the experiments with an actual pipe set up, the Committee desires to have the analyses for metal concentration as well as the taste and odor determinations on the water samples from the test pipes made independently by three water works laboratories. Any water works laboratory willing to take part in this work will find it interesting and valuable from an educational as well as an operating point of view.

In conclusion, I wish to repeat once more the Committee's request for reports of cases where trouble has occurred and where stray alternating currents are believed to be a factor in the trouble. The Technical Sub-committee will study and analyze all such reports, and make field investigations where conditions warrant.

Symposium on Water Quality

Introductory Statement

By George D. Norcom

IN SPITE of the outstanding progress which has taken place in this field of water purification in the last forty years, outbreaks of water-borne intestinal disease have occurred and are continuing to occur as evidenced by the exhaustive study of Gorman and Wolman (Jour. A. W. W. A., 31: 225 (1939)). Among the outbreaks which have occurred, those at Minneapolis and Milwaukee have been of particular interest because the records of routine bacteriological examinations of the finished water in each case indicated satisfactory sanitary quality according to generally accepted standards. As a result of these outbreaks, questions have been raised in some quarters which involve our fundamental concepts of water purification.

The Coordinating Committee on Methods of Water Treatment and Laboratory Control was organized in the summer of 1937 with the object of studying the effectiveness of methods of water purification and the laboratory procedures used in the control of these methods, to promote research in this field, and to serve as a clearing house for information on this subject. The Committee has studied the records of the outbreaks mentioned above and has concluded (Jour. A. W. W. A., 31: 374) that the data now available do not indicate any inherent weakness in available methods of operating and controlling water purification plants in general, nor in the present standards of water quality. Where epidemics have occurred the fault

A statement by George D. Norcom, Consulting Sanitary Engineer and Chemist, 90 Broad Street, New York. Mr. Norcom as Chairman of the Water Purification Division's Committee on Coordination of Methods of Water Treatment and Laboratory Control planned the series of papers which were presented at Atlantic City before the Division on June 14, 1939. The papers by Streeter, Cox, Levine and Schmelkes, to which Mr. Norcom refers will be found on the following pages of this issue of the JOURNAL.

seems to lie in failure to apply fully the available methods of purification and failure to exercise fully the available methods of laboratory control, particularly with regard to the frequency and completeness of bacteriological examinations of the water in course of treatment, as well as the final product. It appears that instead of the formulation of more rigid standards of quality, what is really needed is an intensive effort to make water purification plants throughout the country completely effective and bacteriological control sufficiently thorough.

The questions which have been raised regarding the fundamental theories of water purification include the following:

1. What degree of pollution of raw water is consistent with the production of purified water of satisfactory quality by the various common methods of water purification?

2. Are the existing methods of bacteriological examination and standards of drinking water quality entirely adequate to demonstrate that the water supply does not carry the causative agent of gastroenteritis or other intestinal disease?

3. What is the significance of chlorine-resistant bacteria in water analysis and to what extent are coliform organisms chlorine resistant?

4. What are the factors affecting the efficiency of chlorination and how is effective residual chlorine to be determined?

The classical studies made by the U. S. Public Health Service on the loading of water purification plants were largely directed by H. W. Streeter, Sanitary Engineer. Streeter's studies have been reported in detail by the U. S. Public Health Service and he has been able to demonstrate a relationship between the degree of raw water pollution and the quality of the effluent capable of being produced by various types of treatment and combinations of treatments. The report of the Minnesota State Health Department on its investigation of the typhoid outbreak at Minneapolis stressed the fact that the degree of pollution of the raw water was in excess of the limiting standards of quality proposed by Streeter, but it has been pointed out that this fact in itself would not necessarily mean that the treated water from such a plant was unsafe.

In a booklet entitled "Minimum Sanitary Standards," the Minnesota State Department of Health has indicated certain factors of safety in the purification of water supplies which are based on pollution loads analogous to the raw water standards of quality suggested by Streeter, thus indicating that these standards are being applied in the practical control of water purification. The Wisconsin State

Board of Health has recommended a very high standard of quality for public water supplies if treated by chlorine alone. Moreover, it has been recommended that 100 c.c. portions of water be examined for coliform organisms instead of the methods suggested in the Treasury Standard of five 10 c.c. portions. This standard, if generally enforced throughout the country, would limit simple chlorination to the purification of relatively few water supplies.

The above mentioned recommendations plainly indicate a tendency toward more complete treatment, more elaborate bacteriological methods, and more stringent standards for the treated water. Baylis (Water Works & Sewerage, March, 1939) has gone much further along these lines and definitely states that present standards of quality are not sufficient. He suggests a standard of quality which is much more exacting than the present Treasury Standard and demands almost complete elimination of presumptive gas-forming bacteria in the finished water. He advocates the use of 100 c.c. fermentation tube tests and a much greater frequency of sampling than is at present generally used. He recommends very heavy chlorination for polluted surface waters, including de-chlorination where necessary, and he believes that this type of water should remain in the plant at least 24 hours during purification.

If the procedures outlined above are necessary and if they are to be generally advocated by public health agencies, then it is apparent that many purification plants will have to be expanded or rebuilt and it is not improbable that many raw water supplies now considered satisfactory for purification will have to be abandoned in favor of less polluted sources, unless improved by intensive sanitary development. The Committee is generally of the opinion that purification procedures at many plants should be thoroughly investigated and strengthened where necessary; that the existing equipment should be operated at maximum efficiency and augmented where indicated; and that laboratory control is generally in need of expansion and more intensive application; but whether it is necessary to go to the lengths suggested by Mr. Baylis appears debatable.

About a year ago the principal objects of investigation by the Committee were allocated among its members and the subject of water-borne intestinal disease was assigned to Charles R. Cox, Chief, Bureau of Water Supply, Division of Sanitation, Department of Health of the State of New York. Mr. Cox is also Chairman of the cooperating committee of the American Public Health Association. In his contribution to this symposium, Mr. Cox not only brings up to

date the findings of the Committee on water-borne gastro-enteritis, but also discusses the relationship of these outbreaks to water supply quality.

In utilizing chlorine for the disinfection of public water supplies, an annoying and disturbing factor frequently arises when occasional samples of properly chlorinated water show the presence of confirmed coliform organisms. Similarly, samples from the distribution system sometimes give confirmed positives when samples taken just below the point of chlorine application are uniformly negative. The frequency of these occurrences has brought about a popular belief that certain strains of coliform organisms are more chlorine resistant than others and it has been apparent for some time that this afforded an opportunity for important research work. Everyone has had experience with chlorine-resistant spore-forming lactose splitters which give numerous positive presumptive tests and, rightly or wrongly, the presence of these organisms has been accorded little sanitary significance.

The Committee has been extremely fortunate in securing the cooperation of Dr. Max Levine of the University of Iowa. At the request of the Committee, Dr. Levine has undertaken the examination of a large number of cultures secured from purified water supplies from various parts of the country and purporting to contain chlorine-resistant coliform organisms. Dr. Levine is prepared to present the preliminary findings of this research during this symposium and they should be of the greatest interest to all laboratory workers.

In the debate which has been taking place regarding the efficiency of water purification processes, no single method has received more attention than that of simple chlorination, and this is perfectly natural because this is the one easy, cheap process which can be applied without elaborate construction of plant facilities. It has been repeatedly demonstrated that the control of chlorination of water is far from a simple procedure, particularly when substances are present which interfere with the conventional ortho-tolidine test. As has been demonstrated by Streeter and others, the application of chlorine, when considered as a complete treatment, has definite limitations as regards its ability to produce safe drinking water from a contaminated source. Just what its limitations are has never been definitely agreed upon. Dr. F. C. Schmelkes, Assistant Director of Research of the Wallace & Tiernan Co., Inc., evaluates the factors affecting the efficiency of chlorination and indicates the proper methods for its control in his part of this symposium.

Standards of Raw and Treated Water Quality

By H. W. Streeter

IN CONSIDERING the problem of standards as applied to the quality of water supplies, a distinction should be drawn between this general type of standard and that which prevails in the exact sciences, like physics and chemistry, where measurements are highly precise and relations between cause and effect are quantitatively definite and often capable of satisfactory experimental proof. No such fortunate situation can be said to exist in the field of water sanitation, largely because it is not yet known with any degree of certainty what the relation may be, if indeed any constant quantitative relation exists, between certain measurable characteristics of a water, such as for example its coliform bacterial content as determined by present methods, and the ability or inability of such a water to transmit recognizable water-borne diseases of various kinds. For this reason present standards of water quality, insofar as hygienic safety is concerned, must be regarded now, as in the past, as being temporary and subject to modification as further experience may dictate.

The most widely accepted hygienic standards of water quality which have been used in this country during the past fifteen or more years are those which are commonly known as the Treasury Department Standards for drinking and culinary waters served by the interstate carriers to the traveling public. These standards were originally adopted in October, 1914 for use by the Public Health Service, then a bureau of the Treasury Department, in safeguarding the health of passengers engaged in interstate traffic, as part of its duties in administering the Interstate Quarantine Regulations of the

A paper presented on June 14, 1939 at the Atlantic City Convention by H. W. Streeter, Senior Sanitary Engineer, U. S. Public Health Service, Cincinnati, Ohio. Published by authority of the Director, National Institute of Health, U. S. Public Health Service.

Government. In June, 1925, a revision of these standards was promulgated and the revised Standards have been in use since that time. Both the original and the revised Standards were adopted on recommendations by an Advisory Committee on Official Water Standards appointed by the Surgeon General of the Public Health Service. The personnel of this committee included the names of many distinguished sanitarians, with representatives of this Association and other National scientific organizations.

Application of Treasury Standards

Although the Treasury Department Standards were not intended for general application, as was clearly indicated by the Advisory Committee in recommending their adoption, their use as a general criterion of the quality of municipal water supplies spread rapidly among the various states and they have been adopted by a large majority of state health departments as the basis of sanitary requirements for water supplies throughout these States. The result of this unintended general use of the Standards has been to make them much more widely known and also to have subjected them to a far more critical examination by public health and water works officials than otherwise would have been the case.

In a review before this Association of the experience of the Public Health Service in applying the Standards to certification of water supplies served by the interstate carriers, Tarbett (1) stated, "If the supplies listed for certification may be considered as a cross section of all public supplies, it would be expected that at least 75 per cent of all public supplies would meet the Treasury Standards as a whole and that approximately 90 per cent would meet the bacteriological standards." The difference between these two percentages is a rough index of the extent to which supplies meeting the bacteriological standard failed to meet other requirements, such as refer to sources and protection, cross-connections and so forth.

Among water works men, the bacteriological requirement of the standards is probably most widely known. This requirement provides, in effect: first, that the average coliform index of a water over a test period shall not exceed 1 per 100 c.c. (or a "most probable number" of 1.05 per 100 c.c.), and second, that not more than 5 per cent of the samples examined during a test period shall show a coliform index exceeding 6 per 100 c.c. (or a M.P.N. value exceeding 9.2 per 100 c.c.). Perhaps less well known are certain important engineer-

ing requirements as to the source and natural and artificial protection of water supplies, such as are included above under the term "other requirements." These other requirements, though specified in general terms, are specific in their application and are sufficiently rigid to exclude as unsatisfactory some supplies which may conform ordinarily to the bacteriological standard.

Cases of Possible Failure of Standard

So far as is known to the present writer, only three instances of any degree of prominence have occurred recently in which public water supplies apparently have conformed to the bacteriological requirement of the Treasury Department Standard and at the same time have been implicated as a possible vehicle for the transmission of water-borne disease. One of these was the mysterious outbreaks of gastro-enteritis, apparently water-borne, which occurred in several Ohio River cities during the extreme drought period of 1930–31. During this period the results of routine coliform tests of the delivered water supplies of these cities indicated waters of consistently good quality, meeting the requirements of the Standards, though the raw water tests showed high pollution in many cases. In a report of these outbreaks, Veldee (2) concluded that the evidence strongly suggested the presence of some chemical irritant in the river water, not removable by ordinary water purification methods, whose physiological action simulated a strong purgative. It was definitely known that widespread septic conditions prevailed in the river at that time and many fish were killed by some toxic substance.

The other two instances were the typhoid fever epidemic at Minneapolis in the summer of 1935, which was confined to an area supplied by one of the two filtration plants (the Fridley plant); and the gastro-enteritis outbreak at Milwaukee in February, 1938, before the new filtration plant was placed in service. From evidence collected by the respective state health departments, both of these outbreaks were judged to be most probably water-borne. In both of these cases the records of routine confirmed tests for coliform bacteria indicated that their numbers prior to and during the outbreaks were so low as to bring them well within the upper limit of the Treasury Department Standards.

A possibly significant further indication in both instances, however, was a marked increase in the numbers of presumptive coliforms, or gas-formers, appearing in the tap water immediately preceding the

outbreaks, together with a corresponding increase in the 37°C. plate counts. These latter indications would suggest that some marked deterioration occurred in the sanitary quality of both supplies which was not revealed by the results of confirmed coliform tests. Another possibly significant circumstance, present in both cases, was the fact that just prior to the outbreaks, chlorination was applied only to the raw water (this being the only treatment at Milwaukee) and the chlorine residuals in the treated water were relatively low. At Milwaukee the recorded chlorine absorption value in the raw water was variable and in some samples very high, tending to indicate that underchlorinated water may have been passed into the distribution system, which contained no retention reservoirs near the chlorinators. In this instance, as in the Ohio River outbreaks of 1930–31, there remains, however, the possibility that the outbreak was not of bacterial origin, but was due to some chemical irritant present in the raw water or formed as the result of chlorination in the treated water, or formed by reaction with chlorine.

Ohio River Survey Supports Standard

On the other hand, strong evidence tending to confirm the adequacy of the Treasury Department bacteriological standard has been collected by Veldee (3) from a careful and exhaustive epidemiological study of typhoid fever prevalence during the years 1927–8 in six Ohio River cities, all served by filtered and chlorinated water supplies taken from this river. From the results of this survey, the conclusion was reached by Veldee that no evidence, either direct or presumptive, was revealed implicating the public water supplies of these cities as a vehicle for the transmission of the disease. Ample evidence indicated other modes of transmission. The routine bacteriological examinations of the finished waters at the six cities during the years 1927 and 1928 indicated that with one exception these waters met the primary bacteriological requirement of the Treasury Department Standards in every month. In the single exceptional case, failure to meet this requirement was recorded in 9 of the 24 months, the average coliform index exceeding 4 per 100 c.c. in one month and 2 per 100 c.c. in five months. The failure of the survey to reveal the presence of water-borne typhoid fever in any of these six cities, and especially in the one city whose water supply failed to meet the bacteriological standard during more than a third of the months in the survey period, would tend to support the view that

conformance to the standard should be expected ordinarily to insure a water supply free from responsibility for the transmission of typhoid fever.

The two exceptional cases cited above have tended to raise a question in the minds of some public health and water works men as to the present adequacy of the Treasury Department bacteriological standard, at least for general application to treated waters or to chlorinated surface waters. In a report on the Milwaukee outbreak (4), a tentative standard of quality for chlorinated surface waters has been suggested providing: (1) that the chlorine demand should not exceed 0.2 p.p.m.; (2) that the residual chlorine should at no time be less than 0.2 p.p.m. after 10 minutes of contact; (3) that the 37°C. bacterial count should not exceed 50 per c.c. and (4) that the coliform index should not exceed 0.2 per 100 c.c. In a recent article, Baylis (5) suggests a standard providing, in effect, that the presumptive coliform index should not exceed 0.1 per 100 c.c. and the 37°C. count should average not more than 2 per c.c.

Drastic Revision Not Needed

In view of the long-range evidence as to the adequacy of the present Treasury Department Standards in protecting water consumers against typhoid fever and other similar diseases of known bacterial origin and of the uncertainty which now exists as to the bacteriology of epidemic water-borne gastro-enteritis, the present writer can see no immediate need for undertaking any drastic revision of these Standards, though in the case of chlorinated waters it is his tentative opinion that the application of the bacteriological standard on the basis of the *presumptive* rather than the *confirmed* test for coliform bacteria probably would afford a better working margin of safety in regulating the treatment of such waters. It is also his opinion that a satisfactory water supply should ordinarily meet the bacteriological requirements of these standards in successive periods not exceeding one month, according to the character of the source and adequacy of natural and artificial protection provided for the supply.

Raw Water Standards

Standards of raw water quality thus far considered have been to a large extent bacteriological, in view of the sanitary significance of the bacteriological test and to the fact that drinking water standards from a safety viewpoint have been expressed largely in similar terms. The

first raw water standard adopted in this country, and incidentally the only one which at present has a definite official status, was the International Joint Commission Standard adopted in 1914 for the international boundary waters between Canada and the United States. This standard provided, in effect, that the average coliform bacterial content of raw waters as delivered for treatment should not exceed in any year 500 per 100 c.c., when expressed in terms of the Phelps index. The standard was recommended by a board of experts on the assumption that the average filtration plant when producing an effluent containing not more than 2 coliform bacteria per 100 c.c. (the upper limit fixed by the original Treasury Department Standards) should show an efficiency of coliform organism removal not less than 99.6 per cent.

In the year 1915 the U. S. Public Health Service, recognizing the need of a criterion of limiting pollution for inland rivers and lakes used as sources of purified water supplies, began a series of observational and experimental studies which were designed to furnish an empirical basis for such a criterion. These studies were interrupted by the war, but were resumed in 1923 and continued until 1930. They involved a detailed study of the performance of 31 municipal water purification plants, the construction and operation of an experimental water filtration plant on the Ohio River at Cincinnati and, in this connection, the collection and analysis of data resulting from nearly 150,000 physical and bacteriological tests of raw and treated waters. As the results of these studies have been fully described elsewhere in a series of published reports, (6), no attempt will be made to discuss them here, except to refer to certain practical conclusions drawn from them.

Perhaps the most important result obtained from the studies was the establishment of a basis for fixing upper limits of bacterial pollution for sources of raw water supplies located both in rivers of the type found in the Ohio Basin and elsewhere in the eastern states, and in the marginal zones of the Great Lakes, consistent with the production of effluents meeting any required standard of quality, as expressed either in terms of numbers of coliform bacteria or of bacteria growing on standard agar plates of 37°C. The flexibility of the results in this respect was such that a fairly accurate prediction could be made as to the effect which the adoption of a more rigid, or more lenient, standard of quality for treated waters would be expected to have on the limitation required for raw water pollution. These

results were expressed in a series of relationship curves between the quality of raw and of treated waters, using various combinations of treatment ranging from simple chlorination to the most highly elaborated filtration processes in current use, including two-stage preliminary treatment, and pre-chlorination and post-chlorination.

Although a considerable variation was shown in the efficiency of different individual treatment plants, a surprising degree of consistency was found between the average efficiency of different groups of plants treating raw waters from various sources. The relationship curves between influent and effluent waters derived from the observed average performance for the Ohio River plants thus were found to deviate from similar curves for the Great Lakes and other river plants by a margin so low, throughout a large portion of the ranges covered, as to fall within the statistical error of the combined observations.

For this reason it was possible to derive from the data approximate limits of raw water pollution applicable alike to all types of sources falling within the range of the observations. For example, the rounded upper limit of coliform density corresponding to filtered and chlorinated effluents meeting the primary requirement of the Treasury Department Standard (i.e., containing an average number not exceeding 1 per 100 c.c.) was found to be 5,000 per 100 c.c., within the limits of error for both Ohio River and Great Lakes sources of raw water supply, though the corresponding limits as obtained from the separate observations were 6,000 and 4,500, respectively. From a practical standpoint it has been observed that any general source of raw water supply showing an average coliform density exceeding 5,000 per 100 c.c. or thereabouts, not only imposes an excessive burden on the average filtration plant, in so far as producing an effluent consistently meeting the bacterial requirement of the Treasury Department Standards is concerned, but appears to be generally unsuitable in other respects for producing effluents of satisfactory quality. Later observations along highly polluted rivers like the Ohio and in similarly polluted marginal zones of the Great Lakes have tended to indicate that an average pollution density indicated by a coliform density of about 5,000 per 100 c.c. represents the approximate dead-line between a tolerable and an intolerable degree of raw water pollution, despite the fact, which occasionally has been called to the writer's attention, that in some individual cases purification plants are handling satisfactorily raw waters more highly polluted than would correspond to this level.

The same general principle may be said to apply to the limiting average degree of raw water pollution which can be tolerated safely by the more simple processes such as chlorination. For chlorinated Great Lakes waters this limit was found to approximate 50 per 100 c.c., in terms of coliform numbers. A study of the performance of certain individual chlorination systems located on Lake Michigan has indicated that whenever the coliform density in the raw water has exceeded 50 per 100 c.c., or thereabouts, difficulties have been experienced in producing satisfactory effluents and local outbreaks of gastro-enteritis, where experienced, have almost invariably been preceded by raw water coliform densities exceeding this limit, despite the concurrently favorable results of confirmed tests in the treated water which have sometimes been recorded on these occasions.

Application of Pollution Limits

In summing up this phase of the discussion, it may well be emphasized that average limits of tolerance for water purification systems must be considered on the basis of the efficiency of the average well designed and operated plant, rather than of individual plants, in so far as affording a basis for pollution control in a given river or lake system is concerned. Caution should therefore be exercised in applying such average tolerance limits to individual plants, unless their performance happens to correspond fairly well to that of the average plant of the type serving as a criterion. A limiting pollution base of this kind, to be rational, should represent as nearly as possible average experience at a reasonably high level of plant efficiency, rather than that of an isolated plant here and there. To condemn a suggested criterion because it does not fit all individual cases would seem quite illogical, unless every individual plant were poured into exactly the same mold in respect to its design, operation and resulting efficiency. Such a degree of uniformity is, of course, unreasonable to expect, in view of the varying local conditions which have to be met by different treatment systems.

Conclusion

In conclusion, it may be pointed out that proposals to increase drastically the rigidity of currently accepted standards of treated water quality should be made with a full recognition of the additional burdens which such proposals may be expected to impose on river and lake sanitation. For example, lowering the average coliform stand-

ared limit from 1 per 100 c.c. to 0.2 per 100 c.c. probably would necessitate control of raw water pollution such as to bring the permissible average coliform maximum from about 5,000 per 100 c.c. to a level of the order approximating 200 per 100 c.c., if the extensive observations of the performance of a large and representative group of purification systems under actual operating conditions may serve as a reasonable criterion. Reduction of the standard limit to 0.5 per 100 c.c. similarly would bring the permissible raw water maximum to a level of about 1,500 per 100 c.c. Proposals to require the production of "zero coli" effluents would appear, in the light of these observations, virtually impracticable except in cases where the degree of raw water pollution is consistently low and the use of excessively high dosages of chlorine is permissible. In this connection it should be noted that the chlorine tolerance limit, in so far as taste production is concerned, appears to be somewhat higher in the more alkaline waters such as are found in the northern tier of states than in the less alkaline waters of the middle and parts of the southern tier.

Perhaps at some future time, when stream and lake sanitation has advanced somewhat further than it is at present, a distinct general lowering of the permissible coliform limits in treated waters will be entirely feasible and desirable. Under present circumstances, however, it would seem that efforts might well be directed more especially toward improving the technique and clarifying the interpretation of coliform tests in treated waters, and particularly in chlorinated waters, with a view to detecting significant changes in the bacterial flora of these waters which may be associated with the endemic or epidemic prevalence of water-borne diseases of bacterial origin, including some forms of gastro-enteritis. It is the present writer's opinion that chlorination may tend to modify, or perhaps to attenuate, the cultural characteristics of some bacteria of the coliform group to such an extent that they may fail to respond to the usual routine tests for confirmed coliform organisms. If this should be true, then the sanitary significance of the presumptive coliform index in treated waters will assume a greatly increased importance. This discussion may well be closed, in fact, with the plea for a broader interpretation of the coliform test in treated waters and a critical review of the present tendency toward over-refinement of the test, lest its real sanitary significance be seriously impaired. This, rather than the immediate revision of present quality standards, would seem to be the more fruitful field for present study of the problem.

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Water-Borne Gastro-Enteritis

By Charles R. Cox

THE marked reduction in the incidence of water-borne typhoid fever has led to a false sense of security, if one assumes that the conquest is complete and a matter of history. One must remember, however, that the outbreaks of typhoid fever which have occurred in the last decade or so can be explained by the failure to apply adequate precautions either in the protection of supplies or in the treatment of the water. In other words the failures were largely human rather than due to faulty principles. It is our tasks, therefore, to determine whether the continued occurrence of water-borne disease, especially outbreaks of acute gastro-enteritis, justify loss of confidence in standards of water quality and in the effectiveness of water purification processes, to the extent that more rigid bacterial standards of quality are needed.

There is considerable looseness of phraseology regarding diarrheal disease because several words have been used somewhat interchangeably. For the purpose of this paper, therefore, the word "diarrhea" will be used as a general term describing an important symptom—not a specific, single disease—but rather a group of diseases. The word "gastro-enteritis" is broader and implies involvement of the gastro intestinal track without describing the many symptoms, one of which is usually diarrhea. The word "dysentery" however, is specific in describing a definite disease of two types due to two known groups of pathogenic organisms. Thus, "bacillary dysentery" is the disease due to the *Sh. dysenteriae,* whereas "amoebic dysentery" describes the disease due to the protozoan, *Endameba histolytica.*

The confusion as to the nature of gastro-enteritis has led to several inconsistent theories. For instance, the literature contains references to the theory that the prolific growth of blue-green algae in sources

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of water supply has resulted in water-borne gastro-enteritis, whereas others have expressed the idea that the decomposition of algae and other organic matter, such as leaf mold, may be responsible for certain obscure outbreaks where the bacterial quality of the delivered water seemed to be satisfactory. Still another theory is that water-borne gastro-enteritis may be due to bacteria associated with the serious pollution of water without the polluting organisms being classified as specific intestinal pathogens. A fourth theory having many supporters is that such outbreaks are due to pathogens of unknown nature similar to those causing mild bacillary dysentery, to or the known *Sh. dysenteriae*. On the other hand the occurrence of a few outbreaks, which appeared to be definitely water-borne but which occur without known bacterial pollution of the water, has led

TABLE 1

Incidence of Reported Cases of Water-borne Diarrhea and Dysentery in the United States and Canada for the Period 1920–1936

DISEASE	1920–29		1930–36		1920–36	
	United States	Canada	United States	Canada	United States	Canada
Diarrhea cases	84,145	—	17,458	1,510	101,603	1,510
Bacillary Dysentery Cases	—	—	6	2,000	6	2,000
Bacillary Dysentery Deaths	—	—	0	40	0	40
Amoebic Dysentery Cases	—	—	1,423	0	1,423	0
Amoebic Dysentery Deaths	—	—	98	0	98	0

to a fifth theory that such outbreaks may be due to exotoxins secreted by pathogenic bacteria, or by endotoxins liberated when certain bacteria are destroyed by natural or artificial processes. The presence of irritating chemicals in water would constitute the sixth suggested cause of such outbreaks.

The compilation of information by Wolman and Gorman (Jour. A.W.W.A. **31:** 374 (1939)) was of necessity limited in completness as to data for diarrheal diseases. Thus the information for the period of 1920–1929 does not distinguish between nonspecific diarrheal diseases (gastro-enteritis) and true dysentery, although such a distinction is made in the data for the period 1930–1936. To facilitate this discussion, certain data from this compilation for diarrhea and the two types of dysentery have been transferred to table 1.

Briefly, these data indicate that 101,603 cases of "diarrhea" were reported for the United States during the period 1920–1936, almost half of which, or 45,143 cases, occurred in Detroit in 1926. Moreover, 17,458 cases were reported for the period 1930-1936, during which time only 6 cases of bacillary dysentery and 1,423 cases of amoebic dysentery were reported, all the cases of amoebic dysentery being in Chicago during the outbreak in 1933. Data for Canada are restricted to the period 1930–1936, when 1,510 cases of diarrhea and about 2,000 cases of bacillary dysentery occurred, the latter being restricted to a single serious outbreak in a small community which resulted in 40 deaths. Excluding this outbreak, it is evident that reports of bacillary dysentery are very meagre for both the United States and Canada during the period 1920–1936.

If one eliminates the preponderance of cases of diarrhea (gastro-enteritis) reported for Detroit in 1926, namely, 45,143 cases in the total of 101,603 cases for the United States during a total of 17 years, the data indicate that the chronological distribution of water-borne gastro-enteritis throughout the period 1920–1936 is relatively uniform, showing that there has been no general improvement in the control of such outbreaks. Furthermore, if the same adjustment is made for the Detroit outbreak, it is apparent that water-borne gastro-enteritis was distributed rather uniformly throughout the United States, except for the very favorable statistics for the so-called "mountain states" and "west south central" group of states where a total of only 910 cases occurred throughout this period, as compared to the total of over one hundred thousand.

Furthermore, as in the case of water-borne typhoid fever, the classification of the outbreaks in table 2 as to points of weakness, or points of pollution of the supplies, indicates that about 57 per cent of the total outbreaks of water-borne gastro-enteritis in the United States were due to inadequate control of treatment processes, the next most important point of weakness being the temporary pollution of untreated ground water supplies, representing 15 per cent of the outbreaks. It is also significant to note that outbreaks involving 2,105 cases were due to pollution of supplies at unknown points, and that outbreaks involving 500 cases were of vague character because of lack of sufficient data. Thus about 2.6 per cent of the total number of cases were due to outbreaks regarding which adequate data are lacking.

Special reference is made to the discussion of "controversial out-

breaks" in the Wolman and Gorman summary of nationwide data. Thus outbreaks of water-borne gastro-enteritis, held by some, however, to be "intestinal influenza" spread by contact, occurred in Chicago, Illinois, Kaukakee, Illinois, and Milwaukee, Wisconsin during March, 1936 at a time when all three of the public water supplies apparently were of safe bacterial quality. A second outbreak, at

TABLE 2

Cases of Diarrhea and Dysentery Classified as to Points of Pollution in Water System

CLASSIFICATION	1920-29		1930-36		1920-36	
	No.	Per cent	No.	Per cent	No.	Per cent
United States						
Surface water sources	590	0.7	3,283	17.4	3,873	3.7
Ground water supplies	13,736	16.3	1,782	9.4	15.518	15.1
Seepage of sewage into reservoir	1,269	1.5	196	1.0	1,465	1.4
Inadequate control of treatment	48,725	57.9	9,678	51.3	58,403	56.7
Pollution of distribution system	6,535	7.8	1,979	10.5	8,514	8.3
Pollution of auxiliary intake	11,840	14.1	0	0.0	11,840	11.5
Pollution of auxiliary supply	1,450	1.7	1,969	10.4	3,419	3.3
Total	84,145	100.0	18,887	100.0	103,032	100.0
Canada						
Surface water sources	None reported		2,210	63.0	2,210	63.0
Ground water supplies	None reported		0	0	0	0
Seepage of sewage into reservoir	None reported		0	0	0	0
Inadequate control of treatment	None reported		0	0	0	0
Pollution of distribution system	None reported		0	0	0	0
Pollution of auxiliary intake	None reported		1,300	37.0	1,300	37.0
Pollution of auxiliary supply	None reported		0	0	0	0
Total	—		3,510	100.0	3,510	100.0

Milwaukee in February, 1938, with about 20,000 cases, occurred at a time, however, when there was presumptive evidence of inadequate chlorination.

The 1,500 cases of gastro-enteritis at Coshocton, Ohio, were either water-borne, or were of the nature of "intestinal influenza." This outbreak occurred following the flooding of a well field and a long suction line, but moderate chlorination apparently was successful in

eliminating bacterial pollution, insofar as is shown by the examination of 17 samples collected from the distribution system several days after the height of the outbreak, which samples were free from coliform organisms. Previous flooding of the wells had produced turbid, polluted well water, so in a similar manner pollution may have occurred several days before the outbreak, whereby, allowing for an incubation period of about 48 hours or so, the samples might have been collected 4 or 5 days after the possible date of pollution. Effective chlorination in the meantime would have removed evidence of this temporary pollution.

In a similar manner the reported outbreak of several thousand cases of gastro-enteritis in one section of Tampa, Florida, may have been due to temporary pollution through one of the reported cross-connections, or to leakage into the underwater main serving this section. Such pollution may have been removed by the passage of effectively chlorinated water before the collection of samples which indicated satisfactory bacterial quality of the water.

The Springfield, Missouri, outbreak is of special significance to this discussion, because chlorine treatment apparently was removing the majority of coliform organisms at a time when "paracoli," that is "late lactose-fermenting organisms," were isolated from the chlorinated water delivered during the occurrence of 20,000 to 35,000 cases of gastro-enteritis, 197 cases of typhoid fever and an unstated number of cases of bacillary dysentery causing 21 deaths. Serological tests demonstrated the identity of the late lactose-fermenting organisms isolated from samples of water and from stool specimens collected from patients with gastro-enteritis. The raising of the chlorine dose eliminated the late lactose-fermenting organisms in the chlorinated water and also prevented further illness. It would seem that this outbreak represents a case of "border line" chlorination, without the needed factor of safety, and that it also demonstrated a similarity in the resistance to chlorine of the pathogens causing typhoid fever, dysentery and nonspecific gastro-enteritis.

Finally, it is pertinent at this time to refer briefly to the very unusual series of outbreaks along the Ohio River during the 1930–1931 drought. Briefly, it appears that outbreaks of gastro-enteritis, which were shown by epidemiological evidence to be water-borne, occurred in the fall and winter of 1930–1931 at Charlestown, Huntington, Sisterville and Weston, West Virginia; Ironton, Portsmith and Cincinnati, Ohio; and Ashland and Louisville, Kentucky. Cir-

cumstantial evidence indicates that a wave of polluted water passed down the River during this period, causing gastro-enteritis at progressively lower points in municipalities served with treated river water. The most significant fact is that filtration and chlorination of the river water by these municipalities resulted in the delivery of water free from coliform organisms in the portions examined and with moderate total number of miscellaneous bacteria. At the same time, the water was of very objectionable physical character indicating the presence of decomposing organic matter. The raw water counts and the content of coliform organisms were excessive. Very high chlorine doses were used because of the known degree of pollution of the water. In one instance doses as high as 4.75 p.p.m. were used followed by de-chlorination with sulfur dioxide, in contrast to normal doses of about 0.4 p.p.m. Chlorine doses at other plants during the drought were as high as 2.5 p.p.m. to produce the desired concentration of residual chlorine. In the instance of one supply the delivered water contained between 0.34 and 0.69 p.p.m. residual chlorine throughout the drought period. The consistently favorable bacterial quality of the treated water in the various cities, and the history of uninterrupted chlorination, is supported by the concurrent absence of water-borne typhoid fever. One is forced to conclude, therefore, that energetic chlorination was effective in removing bacterial pollution, but that either bacterial toxins or decomposition products were passing the treatment plant in significant quantities. This important factor will be discussed later.

Data From 29 States

In order to secure more recent information for the United States as a whole, the Coordinating Committee mentioned above sent a questionnaire to the various state departments of health. Replies were received from 29 states, in which general information was given as to 184 outbreaks of gastro-enteritis in 1938, 150 of which were reported in three of the states. Table 3 represents a very brief summary of the information made available in this manner.

Special note should be made of the fact that only 30 of the outbreaks listed in table 3 were definitely water-borne, 27 were suspected to be water-borne, and especially to the fact that 52 were of unknown origin. One must be guarded in manipulating summarized data from 29 separate sources. Reference is made, however, to the fact that polluted water was reported as being delivered to those involved in

45 of the epidemics, greatly exceeding the 30 definite water-borne epidemics, but 12 less than the total of 57 outbreaks which were considered to be either water-borne or suspected to be water-borne. We cannot say from these very general data, therefore, that 12 of these water-borne outbreaks occurred *without* the pollution of water supplies involved, or that the absence of known bacterial pollution was restricted to 12 of the 27 *suspected* water-borne outbreaks. A study of the detailed original data (not available) would be needed to throw light upon this factor. It is very significant, however, that 27 replies expressed the opinion that water-borne gastro-enteritis is

TABLE 3

Summary of Reported Outbreaks of Gastro-enteritis (Diarrhea) in Twenty-nine States, Classified as to Mode of Transmission

Number of States Replying	29
Total Number:	
Water-borne	30
Suspected to be Water-borne	27
Food-borne	34
Suspected to be Food-borne	26
Transmitted by Contact	23
Unknown Mode of Transmission	52
Total Number of Outbreaks	192*
Number of Outbreaks Associated with the delivery of Polluted Water.	45
Number of Outbreaks occurring when apparently Non-polluted Water was Delivered (2 states)	3
Number of States with No Outbreaks	7
Number of States with No Data	3

* 150 of these outbreaks occurred in three states.

not likely to occur in the absence of coliform organisms in the water involved, but that 2 replies reported a total of 3 water-borne epidemics which occurred notwithstanding the absence of known bacterial pollution. No outbreaks were reported in seven states, and information is lacking for three states. These very general data are most significant in representing lack of precise information for many states and also in supporting the inference that the marked apparent difference between the incidence of gastro-enteritis in various states is due largely to the absence of reporting and to the varying emphasis placed upon the subject in the respective states.

Acute diarrheal diseases are reportable in New York State. On the other hand, the absence of serious illness and the short duration of the

attacks minimize the amount of medical care, and thus few physicians have information to report until an outbreak becomes generally recognized. It is not surprising, therefore, that statistics for acute diarrheal disease, or gastro-enteritis, are so indefinite or in fact lacking in many instances. Explosive outbreaks of appreciable size have been investigated because of the fear that they represent conditions which might be a forecast of water-borne typhoid fever, the incubation period of which is much longer than with diarrheal diseases. Data for water-borne gastro-enteritis in New York State previous to 1936, therefore, have been of this general character. For

TABLE 4

1937 Data

Number of Outbreaks of Diarrheal Diseases, Gastro-enteritis and Dysentery in New York State in 1937, Classified as to Mode of Transmission

DISEASE	MODE OF TRANSMISSION					TOTAL
	Water-borne	Milk-borne	Food-borne	Contact	Undetermined	
Gastro-enteritis	22 (673 cases)	2	3	0	14	41
Bacillary Dysentery						
Sonne	2 (104 cases)	0	0	0	4	6
Flexner	0	0	0	1	0	1
Schmidt	0	0	0	0	1	1
Total	24 (777 cases)	2	3	1	19	49

this reason the information for New York State recorded by Wolman and Gorman represents only 1,410 cases in 13 important outbreaks of diarrheal diseases for the period 1920–1936. One of these 13 epidemics occurred at a summer hotel, and the 25 cases of gastro-enteritis were accompanied by 12 cases of typhoid fever and 4 cases of bacillary dysentery. The occurrence of typhoid fever led to the examination of stool specimens, whereby 4 of the total cases of gastro-enteritis were found to be dysentery.

Table 4 gives data as to the 49 outbreaks with a total of 1,645 cases of diarrheal diseases in New York State during 1937, classified as to the mode of transmission, or vector. Thus 24 of the outbreaks,

with 777 cases, were water-borne, 2 were milk-borne, 3 were food-borne, 1 was transmitted by direct contact, and 19 were transmitted by undetermined vectors. Special note should be made of the fact that 8, or 16 per cent, of the total of 49 outbreaks were found to be due to bacillary dysentery, the remaining 41 being classified as non-specific gastro-enteritis. Only 2 of the 8 dysentery epidemics were found to be water-borne.

Table 5 in a similar manner classifies the 87 epidemics of diarrheal diseases in New York State during 1938. Note that 21 of the outbreaks were water-borne, 4 were milk-borne, 23 were food-borne, that

TABLE 5

1938 Data

Number of Outbreaks of Diarrheal Diseases, Gastro-enteritis and Dysentery in New York State in 1938, Classified as to Mode of Transmission

DISEASE	MODE OF TRANSMISSION					TOTAL
	Water-borne	Milk-borne	Food-borne	Contact	Undetermined	
Gastro-enteritis	16 (489 cases)	2	21	1	24	64
Bacillary Dysentery						
Sonne	3 (153 cases)	1	0	1	4	9
Flexner	1 (241 cases)	1	2	2	7	13
Schmidt	0	0	0	0	1	1
Total	20	4	23	4	36	87

4 were transmitted by contact, and 35 were transmitted by undetermined vectors. Also, note that in 1938, 23 or 26 per cent of the total of 87 epidemics of diarrheal diseases were due to bacillary dysentery, or nearly twice the percentage obtaining in 1937. There is no evidence to indicate that there was any relative increase in the incidence of dysentery, but rather that the more prompt and extensive collection of stool specimens resulted in the more general isolation of the specific intestinal, pathogenic organism, *Sh. dysenteriae.*

The numerous data summarized in tables 4 and 5 have not been shown in detail to conserve space. Certain important aspects of this information, however, should be emphasized. For instance, only two of the total of 44 water-borne outbreaks of diarrheal diseases during

1937–1938 were transmitted by public water supplies, the remainder being transmitted by the water supplies of camps, summer hotels, rural schools and an airport.

One of the two epidemics in municipalities was nonspecific gastro-enteritis in a small village where 141 cases occurred in a population of about 800. The supply is secured from a relatively large impounding reservoir on a small stream draining a farming area. Direct sewage pollution does not occur, but the degree of animal pollution is significant. Furthermore a second impounding reservoir was being constructed on the same watershed above the intake, which increased the chlorine demand of the water, and also the likelihood of temporary pollution of human origin, although the latter was guarded against as far as possible by providing special toilet facilities for the workmen. Treatment was by pressure filters without effective coagulation and by post-chlorination. While there was no record of a lapse in chlorination and while the doses of chlorine were recorded as sufficient to maintain a residual of 0.05 to 0.10 p.p.m. after a contact period of *several days* in an equalizing reservoir, the chlorine demand of the filtered water during the outbreak was very high, namely 1.3 p.p.m., this following a period of rainfall. One would expect this demand to fluctuate rapidly during construction activities. In addition, the chlorinator failed a short time after the outbreak in a manner suggesting that the same condition may have occurred before without being reported.

Subsequently study showed that the cases occurred during a period of three weeks, the largest number being restricted to the second week. By chance, a sample for routine bacteriological examination was collected from a faucet on the distribution system, about the end of the first week of the outbreak by a local official, not knowing of the incidence of gastro-enteritis. This sample was free from coliform organisms in all five 10 c.c. portions examined and the agar count was 20 per c.c. When this outbreak became known toward the end of the third week of onset of cases, numerous samples of treated water were collected from various points on the distribution system and were found to be free of coliform organisms in the portions examined. The raw water by that time apparently had returned to the normal degree of pollution represented by a coliform index of about 240 per 100 c.c.

Unfortunately only three stool specimens could be collected and

these only during the termination of the epidemic, the results of the examination of which were negative.

The incubation period of 3 to 4 days and the duration of illness of one-half day to one week suggests a bacterial infection rather than toxic poisoning. Furthermore, the delivered water did not have an objectional taste and odor. The presumption is that temporary contamination of the supply with infectious organisms occurred at a time when the chlorinator failed to operate on several occasions of short duration. At least it is significant that only several cases occurred after the day of the investigation when there was definite knowledge of the effectiveness of chlorination and of the satisfactory quality of the delivered water. The incubation period of 3 to 4 days would explain the late date of onset of these few cases.

The other epidemic definitely transmitted by a public water supply consisted of 84 cases of Sonne dysentery in a population of about 3,500. Stool specimens were collected from 34 patients, from which the specific pathogenic organism was isolated in 14 instances. This epidemic was due to the failure of equipment to feed hypochlorite solution during the greater part of one day, until the difficulty was noted by the operator upon his visit to the equipment the following day.

Only 4 of the remaining 42 water-borne epidemics at camps, hotels, etc., were due to failure in treatment consisting of chlorination only, 37 of the outbreaks being due to the pollution of untreated supplies from wells, springs, or lakes, and, finally, 1 epidemic was due to the pollution of newly laid water mains at an airport, which mains were placed in use without disinfection.

It is very significant to note that the water supplies involved in *all but one* of the definitely established water-borne epidemics were found to be subject to bacterial pollution, the exception being the public supply of the village noted above. In fact, it was the occurrence in 1937 of this water-borne outbreak, with an apparent absence of pollution of the delivered water, that led to a more intensive investigation during 1938.

It was realized that more would be gained by stressing in 1938 the examination of stool specimens collected from those suffering from gastro-enteritis rather than by attempting to isolate pathogenic bacteria from samples of water. In many instances, however, the occurrence of outbreaks was not known in time to enable collection

of representative specimens. Nevertheless, it was possible to secure stool specimens in connection with 9 of the 20 outbreaks of diarrheal diseases deemed to be water-borne in 1938, whereby it was found that 4 of the outbreaks were due to bacillary dysentery; 5 were unclassified but organisms were isolated in 2 instances which had some of the characteristics of the paratyphoid-enteritidis group.

On the other hand, the late receipt of knowledge of outbreaks and the inability to collect promptly a larger number of stool specimens, resulted in only 23 of the total of 87 epidemics of diarrheal diseases being classified definitely as bacillary dysentery. In 12 of these 23 instances, the definite clinical data as to dysentery were not accompanied by equally definite epidemiological data as to the vector, so these 12 had to be classified as of undetermined mode of transmission. It is suspected, however, that many of these dysentery epidemics of undetermined vector actually were water-borne.

The only way in which precise information can be made available as to the nature of water-borne gastro-enteritis is through the isolation of known or suspected pathogenic organisms from stool specimens, the pathogenicity of which is determined by serological tests with samples of blood collected from the recovered patients. Unless this is done, great confusion will occur because of the variety of bacteria present in polluted water and in intestinal discharges. In other words, it is necessary to know more than that the water delivered to any group of people involved in an outbreak is subject to pollution by coliform organisms, or that certain suspected bacteria are present in a sample of water or in stool specimens.

The above data indicate that practically all water-borne gastro-enteritis is of the nature of bacterial infection causing mild dysentery due to known or unknown pathogenic bacteria, but that a few water-borne outbreaks may be similar to "food poisoning" due to bacterial toxins or to the products of bacterial decomposition of organic matter in the raw water. The crux of the problem seems to be to determine the significance, if any, of toxins and decomposition products, as contrasted to bacterial infection.

The Rôle of Bacterial Infections

Information is limited as to intestinal pathogens, as indicated by the following quotation from the volume entitled "Bacteria of Typhoid, Salmonella and Dysentery Infections" by Havens, namely,

that "complete identity of the organisms which may cause diarrhea or dysentery has not yet been accomplished nor have the limits of variation of recognized types been accurately determined."

The discussion of the pathogenicity and significance of the many intestinal bacteria isolated by various workers in connection with diarrheal diseases would be out of place in this paper. Restricting the subject to the data for New York State, it appears that sufficiently detailed information tends to disclose: (a) water-borne gastro-enteritis to be mild dysentery resulting from infection by a member of the *Sh. dysenteriae* group; (b) that milk-borne outbreaks are either dysentery, or toxin poisoning due to previous growth of *Staphylococcus aureus* in infected milk; (c) that food-borne outbreaks are dysentery, or of the nature of food poisoning incidental to infections by the paratyphoid-enteritidis group.

Data are lacking as to water-borne gastro-enteritis being due to pollution of water by staphylococci, such as the specific organism responsible for milk-borne gastro-enteritis, when the infected milk is secured from cows suffering with mastitis, or has been infected by pus discharges from boils, etc., of milkers. This is of significance in connection with bacterial toxins, to be discussed later.

Pollution from Animals

Pollution of animal origin should be considered in connection with water-borne gastro-enteritis, especially with supplies receiving farm drainage from large numbers of cattle and pigs. The only clear-cut evidence of this nature for New York State, however, is that of an explosive outbreak of gastro-enteritis which resulted from temporary but serious pollution of a spring-fed reservoir by surface drainage, following the rapid melting of snow which had covered manure, at a time when diverting ditches failed. The degree of pollution was sufficiently great to impart a characteristic odor to the water. Unfortunately, this outbreak was not known until it was too late to collect representative stool specimens, so the organisms involved are not known. The only tentative conclusion possible at this time, therefore, seems to be that very concentrated pollution of animal origin, at a time when specific bacteria are involved, might cause explosive outbreaks of gastro-enteritis. In general, however, pollution of human origin seems to be of chief significance in this connection.

Intestinal Pathogens in Sewage and Polluted Water

Granting then that an appreciable group of intestinal pathogens may be of significance in water-borne diarrheal diseases, it is pertinent to consider the relative number of such organisms in comparison with the number of coliform organisms used as indicators of bacterial quality.

Quantitative information is lacking, but it is known that normal sewage contains a very large number of coliform organisms from both healthy and diseased individuals, so these indicators of pollution predominate over pathogenic organisms even though certain individuals among the sewered group may be carriers of specific intestinal diseases. The coliform index, therefore, continues to be a sensitive index of fecal pollution, in that it is more sensitive than any numerical value for pathogenic bacteria.

Unfortunately, the number and distribution of carriers of known intestinal diseases is not available, with the exception of information as to typhoid carriers which are not under discussion at this time. It is generally accepted by the medical profession, however, that there are few chronic dysentery carriers, although recovered patients may be carriers for a period of several weeks or months. While not conclusive, it is significant to note that during an examination of healthy food handlers, 1.2 per cent of the 2,798 examined were found to be carriers of the organism known as *S. morgani*, which was first isolated during an outbreak of infantile diarrhea, and which has been held responsible for water-borne gastro-enteritis.

In the absence of more precise data, therefore, it may be concluded that the sewage from any appreciable aggregation of people is very likely to contain organisms of the dysentery group as well as unknown pathogenic organisms of this character. All sewage, therefore, should be regarded as infectious.

Resistance of Intestinal Pathogens

All of the known intestinal pathogenic bacteria are non-spore-bearing bacteria similar in character to *Eb. typhosus, Esch. coli*, etc., the resistance of which is established to a considerable degree. Due allowance should be made for the influence of variation in resistance of each variety of bacteria, so a range in the degree of resistance of different bacteria to chlorination, for example, is to be expected. This variation in resistance to chlorination and the resulting higher doses of chlorine required to kill the more resisting forms, however,

does not appear to be greater in magnitude than the excess chlorine dose needed as a factor of safety. This conclusion, of course, is supported by the fact that all the water-borne outbreaks, where complete information was available, were transmitted by water known to be subject to bacterial pollution, with the exception of the controversial outbreaks discussed above. It will be recalled that a moderate increase in chlorine dose at Springfield, Missouri, over that needed to destroy *Esch. coli*, resulted in the elimination of *paracoli* (late lactose fermenting bacteria) and in the control of the outbreak of typhoid fever, dysentery, and gastro-enteritis.

Amoebic Dysentery

Dysentery due to pathogenic protozoa, such as *E. histolytica*, is quite distinct from bacillary dysentery and gastro-enteritis. In passing, however, reference is made to the fact that the number of carriers of amoebic dysentery has been computed from numerous surveys in various parts of the country and has led to the estimation that approximately 10 per cent of the general population may harbor the cyst of *E. histolytica*, the estimate for Chicago being about 4 per cent. This fact, however, seems to have little practical significance because of the few known water-borne outbreaks of amoebic dysentery in the United States. It seems that only fresh and serious pollution of potable water leads to the transmission of this disease. Furthermore, filtration is effective in removing the organisms, although their resistance to chlorination is still uncertain, because of conflicting reports. Thus resistance to chlorine doses of 500 p.p.m., producing 165 p.p.m. residual chlorine after 48 hours, has been reported, whereas more recent literature reports the destruction of the cysts of the organism in 20 minutes with doses sufficient to give a residual of 2.0 p.p.m. Be that as it may, the important fact is that amoebic dysentery is not a problem in New York State, and does not complicate the control of water-borne gastro-enteritis.

Bacterial Toxins

Specific toxic substances are secreted by certain pathogenic bacteria, such as the so-called exotoxin secreted by *Staphylococcus aureus* in milk, thus causing milk-borne gastro-enteritis. Exotoxins are liberated only when specific bacteria find favorable conditions for growth, such as in milk, custard pies, and other food products. As far as we can learn, the conditions in natural waters, including

seriously polluted water, are not favorable to the *growth* of pathogenic bacteria which produce specific exotoxins. At least the epidemiological and clinical distinction between most outbreaks of water-borne gastro-enteritis on the one hand and milk- and food-borne gastro-enteritis on the other hand indicate the former to be bacterial infections having incubation periods of 1 to 7 days, whereas many of the latter are identical to those resulting from the consumption of contaminated milk or food which has supported bacterial life and in which exotoxins were liberated previously to consumption. The toxic outbreaks may occur in a period as short as several hours after the consumption of the milk or food, as contrasted to longer incubation periods with bacterial infections.

While exotoxin-producing pathogenic bacteria probably do not develop in water, consideration must be given to the possibility of the release of endotoxins by certain bacteria when they are destroyed in water by natural causes or by water treatment processes, such as chlorination. It should be noted, however, that the total weight of bacteria in even heavily polluted water is very low, and thus the quantity of any endotoxins which may be released is correspondingly lower. Dilution in natural waters and other unfavorable factors would still further reduce the concentration of such toxins. Bearing in mind the known specificity of the existing agents, it is concluded that the contamination of water with specific bacteria which liberate endotoxins upon their death, would have to be much greater in degree than is likely to be the case with potable water supplies.

Rôle of Decomposition Products

The unattractive physical character of many water supplies during outbreaks of water-borne gastro-enteritis has suggested to many that the decomposition of organic matter may have resulted in the production of protein cleavage products which are irritating to the gastro-intestinal tract. The literature contains many references to the possible toxicity of such products, formerly associated with so-called "ptomaine" food poisoning. The more recent medical view, however, seems to be that any appreciable concentration of such products would render the food unpalatable because of spoilage, whereas the presence of specific bacterial toxins in water, food or milk is not detected by the senses. Furthermore, there are numerous records of the consumption by large numbers of people of unattractive water containing decomposing organic matter without gastro-enteritis

occurring. Filtration and chlorination does not remove the soluble organic matter, although the concentration may be reduced by effective coagulation, and the material may be modified somewhat in character by chlorination. The treated water, however, is likely to retain a considerable portion of the soluble organic matter normally present in the raw water. The sudden onset and termination of water-borne gastro-enteritis also supports the view that some temporary contamination of the water occurs, which is different in character to that of the usual organic pollution of water. Some special condition must obtain, therefore, to explain toxic effects or irritation of the gastro-intestinal tract in the absence of bacterial infections.

The outbreaks along the Ohio River in 1930–1931 did not present the typical clinical picture of bacterial infections, there being strong evidence that the causative agent was a chemical, gastro-intestinal irritant. This is supported by unpublished data from Louisville to the effect that during the outbreak diarrhea was induced in guinea pigs by feeding them tap water and also the same water after boiling. This indicates that the irritant was resistant to boiling. It was reported that boiling the water for a few minutes removed the objectionable taste and odor, which may show that the remaining irritating substance was not apparent to the senses.

Assuming that exceptional outbreaks are due to irritating substances, then more stress should be placed upon effective coagulation and possibly activated carbon treatment in the hopes that the toxic materials will be adsorbed.

The growth and subsequent decomposition of algae were noted in connection with several outbreaks of gastro-enteritis transmitted by an untreated supply secured from an isolated mountain lake not exposed to permanent pollution. Later it was found that fishing from boats occurred in the vicinity of the intake. Subsequent chlorination of this supply has eliminated such outbreaks, but obviously, has not reduced the organic content of the water, thus indicating that bacterial infection due to temporary pollution was responsible for the former difficulty, rather than the decomposition of vegetable matter.

Summary

In summary, we wish to emphasize that the general pollution of potable water supplies with decomposing organic matter and miscellaneous bacteria of sewage origin is much more common than the

occurrence of water-borne diarrheal diseases, indicating that a specific causative agent is present temporarily in supplies transmitting such diseases. While complete information is lacking, the available data disclose water-borne gastro-enteritis to be a bacterial infection resulting from the consumption of water contaminated by organisms of the dysentery group or similar pathogens, which specific bacterial pollution is accompanied by coliform organisms. The New York State data do not support the view that such outbreaks may be due at times to the growth and decay of algae, nor to the products formed by the typical decomposition of organic matter. Isolated outbreaks may be due to some unknown but specific modification of organic matter in seriously polluted water, whereby substances irritating to the gastro-intestinal tract are formed. One must rule out toxic industrial wastes and other direct chemical pollution before a definite conclusion can be reached as to such outbreaks.

The New York State studies are to be continued. Furthermore, the United States Public Health Service recently instigated a more intensive research into water-borne disease. This work is aided by the availability of new media for isolating intestinal pathogens. This development should encourage the needed study of the bacteriology of both endemic and epidemic diarrhea and dysentery and also of the extent and distribution of carriers of diarrheal diseases.

Conclusions

It would seem that the information discussed above permits the following conclusions, bearing in mind the general character of most of the data:

1. That more information is needed as to the extent and character of water-borne gastro-enteritis.

2. That, insofar as New York State data based upon definite information are concerned, this disorder has been found to be of the nature of mild dysentery due to specific pathogenic bacteria being present in the delivered water, that is the outbreaks are due to specific bacterial infections and not to pre-formed toxins or irritating substances.

3. That under abnormal conditions not observed in New York State, irritating substances may be produced by the atypical decomposition of organic matter in water, or by the presence of specific chemical irritants.

4. That gastro-intestinal disorders due to chemical irritants are

not likely to occur, except when the raw water is very seriously polluted.

5. That more attention should be paid to the type and degree of pollution of raw water and in the control of treatment processes.

6. That, based upon available information, the present bacterial standards of water quality are adequate for the control of diarrheal diseases, if they be considered in connection with pertinent physical and chemical data.

7. That present water treatment processes likewise are adequate, when properly controlled and when they are not overloaded.

Discussion by *Robert Spurr Weston.* * The compendious paper by Mr. Cox leads the writer to contribute some of the results of both his casual and his careful observations in the Connecticut River Valley during many years.

In this valley are several colleges,—Wesleyan at Middletown, Trinity at Hartford, American International at Springfield, Mt. Holyoke at South Hadley, Amherst and Massachusetts State at Amherst, Smith at Northampton, and Dartmouth at Hanover. Also, there are many large schools, such as Williston at Easthampton, Mt. Hermon at Northfield, and the New Hampshire State Normal School at Keene.

Most of these institutions are supplied with municipal water of various kinds. The colleges at Hartford and Springfield are supplied with stored and filtered water, as is the Normal School at Keene. Mt. Hermon and Williston are supplied with ground water, and most of the remainder with stored upland water, in some cases chlorinated, in others not.

In many of the schools, incoming students suffer short, often painful, but rarely serious attacks of gastro-enteritis; in others, they do not. At the same time, the permanent residents in school or town are usually immune to these attacks.

The writer remembers his own suffering after he entered Amherst over fifty years ago. Since then, the impounded colored water supplying the college and town has been chlorinated to the limit of tolerance, yet newcomers still have to "get used to the water." This condition exists at Smith College, similarly supplied, but not at

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Mt. Holyoke College, eight miles away, supplied from shallow wells. Students at Dartmouth supplied with stored unchlorinated water containing a few *Coli-Aerogenes* (18.8 per cent positive 10 ml. portions, on the average) must acquire immunity for their comfort.

Report on Keene, N. H.

The most illustrative case in the writer's experience is the one at Keene, N. H. In this city, visitors, particularly the incoming students at the Normal School and commercial travelers, frequently suffered severely from gastro-enteritis, while the regular residents suffered far less.

About October 16, 1923, a severe outbreak occurred. The malady was characterized by severe intestinal pains and sufferers were frequently forced to their beds for a day or more. Following this outbreak, the late Prof. George C. Whipple of the Harvard Engineering School and the writer made a study and report to the city.

The main water supply for the city was drawn from an almost uninhabited region, there being only two houses on the six square miles of catchment area. The region was wooded and the roads through the woods were seldom traveled.

The water from the storage reservoir was let down an open brook below to two successive small reservoirs which supplied the respective high and low services in the city. The water was soft and reasonably low in color and organic matter and while drawn from storage was actually taken from an open brook after but little storage in the small intake reservoirs downstream. The water in the brook was subject to accidental contamination by persons or animals and received the washings from the soil.

Just before the epidemic on October 16, there was a rainfall of 0.12 inch and the autumnal turnover in the main reservoir was occurring.

The conclusion reached in the study was that the gastro-enteritis was due to contamination, perhaps due in turn to washings from the soil combined with short storage, or to the results of the overturn in the reservoir. The State Board of Health was of the opinion that the trouble was due to fecal pollution, members of the Coli-Aerogenes group being found in considerable numbers. Prof. Whipple and the writer placed the burden upon soil bacteria (perhaps gas-forming), and thought the most likely cause was the facultative anaërobic or

anaërobic bacteria residing in the reservoir bottom during the summer period of stagnation and brought up by the fall overturn. If fecal bacteria were to blame, how could the occurrence be so largely seasonal and autumnal?

Storage, chlorination and filtration were considered. The State Board believed chlorination alone would suffice, but slow sand filtration was thought best and was accepted as sufficient by the Board.

Since the filters were placed in service in 1925, visitors to the city have not been afflicted. Meanwhile, many autumnal visitors to other towns in the valley supplied with stored chlorinated upland water have to become accustomed to it.

The writer, therefore, agrees with Mr. Cox that the probable cause of gastro-enteritis such as occurs in the fall of the year is due to a chlorine-resisting bacterium, probably a resident of the soil, possibly an anaërobe or a facultative anaërobe.

It is hard to believe that any conceivable amount of any byproduct of the biochemical decomposition of vegetable organic matter can cause this particular affliction and because it is usually accompanied with severe aeroenterectasia. The profession is greatly indebted to Mr. Cox for his analytical study of an annoying complaint.

Discussion by *Charles R. Cox.* Due to the involved nature of many of the data discussed, it seems desirable to emphasize that positive conclusions cannot be reached which will indicate whether there is only a single inciting agent of *all* outbreaks of water-borne gastro-enteritis or what is the nature of such an agent. In the light of Mr. Weston's discussion, however, we wish to repeat the following conclusions based upon *data collected in New York State.*

1. That where comprehensive information is available, water-borne gastro-enteritis is shown to be due to the consumption of water polluted with the pathogenic organism, *Sh. dysenteriae*, or to some unidentified organism which probably belongs to the Salmonella-Enteritidis group.

2. That three factors are needed to indicate the exact causative agent for water-borne gastro-enteritis, namely, consumption of water exposed to pollution of human origin which is either not treated or ineffectively treated; secondly, the recovery of known pathogenic organisms from stool specimens collected from those suffering with gastro-enteritis; and, thirdly the identification of any organisms so

isolated as being in fact the causative agent through serological tests made with blood samples collected from those recovered with the specific outbreak of gastro-enteritis.

3. When such precise and definite epidemiological and clinical evidence is lacking, it is impossible to determine whether or not any miscellaneous or specific organisms present in polluted water are responsible for gastro-enteritis among those consuming the water.

4. That it is essential for chief stress to be placed upon clinical and serological evidence before organisms associated with the decomposition of organic matter can be proven to be the causative agent of water-borne gastro-enteritis.

Bacteria from Chlorinated Waters

By Max Levine, Philip Carpenter and J. M. Coblentz

THIS is a report of a study undertaken on the characteristics of organisms, presumably of the coliform* group, isolated from chlorinated waters. There have been submitted 162 cultures from 97 water samples from five cities. Quite a number of the cultures were not pure as it was specifically designated that no attempt at purification, beyond fishing well isolated colonies, be made. On arrival in our laboratory they were transplanted into lactose broth and then plated out on E. M. B. agar and several well isolated colonies fished from each plate.

There were originally obtained in this manner 350 strains, but this has been reduced to 282, for this report, through the elimination of cultures which were presumably duplicates, that is, their characteristics were identical with some other cultures fished from the same plate. A large proportion of the cultures came from Lake Michigan; 67 strains were isolated from 47 samples of water, temperature of which was less than 5°C., and 215 strains were obtained from 50 samples of water, the temperature of which was between 12° and 22°C. These will be referred to as the winter and summer series respectively.

A paper presented on June 14, 1939 at the Atlantic City Convention by Max Levine, Professor in Charge, Dept. of Bacteriology, Iowa State College, and Bacteriologist of the Iowa Engineering Experiment Station, Ames, Iowa; Philip Carpenter, Instructor, Dept. of Bacteriology, Iowa State College; and by J. M. Coblentz, Research Assistant, Engineering Experiment Station, Iowa State College.

* The term "coliform" as used in this paper conforms to the editorial practice of this Journal. (See Jour. A. W. W. A., **29**: 1999 (1937).) The coliform group "includes (1) aerobic or facultative anaerobic (2) Gram-negative (3) non-spore-forming organisms which (4) ferment lactose with (5) gas formation. This is the coli-aerogenes group of the eighth edition of *Standard Methods*. It includes the genera now called *Escherichia* as well as those called *Aerobacter*. It also includes the *Citrobacter* family. It is not specific for *Esch. coli* nor is it specific for *Aer. aerogenes*."

The following report is preliminary in nature and will be subject to some revision as the results of continued attempts to purify the cultures accumulate. There are a number of cultures which may consist of two closely allied varieties of the coliform group or other bacteria.

Chlorination and Residual Chlorine of Water Samples

Specific information on method of chlorination was available for 93 of the water samples. Of these, 49 were treated with chlorine alone, 35 with ammonium sulfate and chlorine, and 9 with ammonium sulfate and chlorine supplemented by re-chlorination. Assuming that a residual of 0.4 p.p.m. of chlorine for a period of not less than 30 minutes (all samples had a contact period of not less than 30 minutes) or that 0.2 p.p.m. residual chlorine for a contact period of not less than 2 hours constitutes adequate chlorination, as measured by our present methods, it will be noted from table 1 that 34 (70 per cent) of the 49 samples treated with chlorine would have been considered adequately chlorinated at the time of sampling, whereas, of the 44 samples treated with ammonia and chlorine all but one would fall in the category of adequate chlorination. It may further be noted that there were 66 samples (71 per cent) which showed more than 0.4 p.p.m. residual, 89, or 95 per cent of the samples, more than 0.2 p.p.m. and attention is called particularly to the fact that 29 (31 per cent) of the 93 samples had residuals of over 0.4 p.p.m. with a contact period of over 4 hours.

The organisms isolated are therefore considered to constitute, in general, a group obtained from well chlorinated supplies as judged by our present standards and chemical methods of evaluation of effective chlorination.

Considering that organisms of the non-spore-forming coliform group and closely allied bacteria were isolated from about 95 per cent of these samples, questions naturally arise as to whether (1) these organisms are really resistant (2) protected by some constituent of the water or by clumping and (3) whether our methods of determining residual chlorine as an index of germicidal efficiency need be re-evaluated.

The following discussion will relate primarily to a consideration of organisms of the coliform group isolated.

Of 196 strains of the coliform group isolated, 28 (14.3 per cent) were allocated to the genus *Escherichia*, 85 (43.3 per cent) to the

genus *Aerobacter* (on the basis of the Voges-Proskauer reaction and growth in citrate media), whereas 83 (42.4 per cent) fell into the "intermediate" group, that is they grew on citric acid but did not give the Voges-Proskauer reaction. The distribution of these strains with respect to the amount of gas produced in the presumptive test lactose broth from which they were originally isolated is shown in

TABLE 1

Residual Chlorine and Period of Contact in Waters from which Cultures were Submitted for Identification

CONTACT PERIOD		P.P.M. RESIDUAL CHLORINE				TOTAL SAMPLES	
		Under 0.2	0.2-0.39	0.4-0.59	0.6 or more		
		Number of Samples				No.	%
Less than 1 hr.		‹1›	‹5› 1	‹10› 1		18	19
1-2 hr.		‹3›	‹5›	‹1› 13	2	24	26
2-4 hr.			1	‹1› 1	‹2› 1	6	7
4-6 hr.			‹7› 6	‹7› 10		30	32
6 hr. or more		‹1›	‹1› 1	‹5› 6	1	15	16
Total Samples	No.	5	27	55	6	93	
	%	5	29	59	7		100

‹No.›—Treated with Cl_2 only.
Others—Treated with $(NH_4)_2SO_4$ and Cl_2.
%—To nearest whole number.
No.—All samples.

table 2. It will be noted that 125 (63.8 per cent) of the strains were obtained from questionable presumptive tests in which generally less than 5 per cent gas was produced in 48 hours at 37°C. These slow gas formers were not restricted to the *Aerobacter* and "intermediate" group, in fact they were proportionally most common in tubes from which *Escherichia* strains were eventually isolated, as may be seen from the fact that 48 (58 per cent) of the 83 "intermedi-

ates," 57 (67 per cent) of the *Aerobacter*, and 20 (72 per cent) of the 28 *Escherichia* strains were obtained from questionable lactose broth presumptive tests. The data illustrate very clearly the hazard of losing coliform group organisms if questionable lactose broth tests (even if only a bubble of gas is produced in 48 hr. at 37°C.) obtained on chlorinated surface waters, are discarded, and emphasize the importance of following through any suggestion of the presence of gas formers if the maximum coliform index is really to be ascertained.

TABLE 2

Relation of Gas Production in Original Lactose Broth Presumptive Test to Type of Coliform Group Organisms Isolated from Chlorinated Water

% GAS IN PRES. TEST 48 HR. 37°C.	UNDER 5	10	15-25	30 OR MORE	NO REC.	TOTAL	PER CENT
Escherichia	20	3	2	2	1	28	14.3
Aerobacter	57	4	7	7	10	85	43.3
Intermediate	48	2	4	16	13	83	42.4
Total	125	9	13	25	24	196	
Per Cent	63.8	4.6	6.6	12.8	12.2		100.0

TABLE 3

Correlation of Type of Coliform Organism Isolated with Reported Appearance on E.M.B. from Presumptive Test

E.M.B. FROM PRES. TEST	COLIFORM GROUP		QUESTIONABLE		TOTAL	
Colon subgroup	No.	%	No.	%	No.	%
Escherichia	2	7.1	26	92.9	28	14.3
Aerobacter	10	11.8	75	88.2	85	43.3
Intermediate	21	25.3	62	74.7	83	42.4
Total	33	16.8	163	83.2	196	100.0

In table 3 is shown the distribution of the strains isolated with respect to the reports by the individuals submitting the original cultures as to appearance of colonies on E. M. B. agar plates made from their presumptive tests. It may be noted that of the 196 strains only 33 (17 per cent) were from E. M. B. plates considered as containing typical members of the coliform group. In this connection it is interesting also to note that only 2 (7 per cent) of the 28

Escherichia strains, and 10 (11.8 per cent) of the *Aerobacter* cultures in contrast to 21 (25.3 per cent) of the "intermediate" types of coliform organisms came from plates which were reported as containing typical coliform group colonies.

It appears from the foregoing that cultures which were submitted for study were atypical not only as respects their gas producing qualities in the presumptive lactose broth media, but also in appearance on the confirmatory test media, so that dependence upon the partially confirmed test might also result in excessive losses of coliform organisms and, consequently, a low coliform index.

Relation of Season and Temperature to Gas Production

Of the 196 strains of the coliform group studied, 37 were isolated during the winter (November, 1937 to February, 1938) when the temperature of the water was less than 5°C. The remaining cultures (159) were obtained from waters with temperatures of 12° to 22°C., during the months of June and July, 1938. In the course of the studies it appeared that the season of isolation was definitely associated with some of the characteristics of the isolated strains of the coliform group. This was particularly true with respect to the effect of temperature of incubation on the activities of the micro-organisms. A perusal of table 4 discloses that the distribution of the winter and summer strains with respect to volume of gas produced from standard lactose broth at 30°C. did not differ as may be seen from the fact that 32 (or 87 per cent) of the 37 winter and 145 (or 91 per cent) of the 159 summer strains produced 10 per cent or more gas at 30°C. When these cultures are compared on the basis of gas producing properties at 37°C., however, a very marked difference is observed, in that 33 (or 89 per cent) of the 37 winter strains and only 77 (48 per cent) of the 159 summer strains produced 10 per cent or more gas from standard lactose broth when incubated at the higher temperature. Among the remaining 82 (or 52 per cent) of the summer strains, are included 22 (14 per cent) which produced less than 5 per cent gas and 60 (or 38 per cent of all summer strains isolated) which formed no gas at all from lactose broth at 37°C. in 48 hours (gas was formed on longer incubation).

Considering only those strains which produced 10 per cent or more gas at 37°C., it will again be noted that there was no difference between the summer and winter strains with respect to their gas producing properties at 30°C. Thus of the 33 winter strains only 2

(5 per cent) produced less than 10 per cent gas at 30°C. and of the 76 summer strains only 1 fell in that category. On the other hand considering the cultures which produced 10 per cent or more gas at 30°C., it will be noted from table 4 that, whereas only 1 (3 per cent) of the 32 winter strains was a poor gas former at the higher temperature, there were present among 145 summer strains 69 (approximately 48 per cent) which produced less than 5 per cent gas and of these 47 produced no gas at 37°C. in 48 hours. This marked and striking

TABLE 4

Relation of Season of Isolation and Temperature of Incubation to Gas Production from Lactose Broth

		% GAS AT 37°C. (48 HR.)			TOTAL	
		0	<5	10 or more	No.	%
% Gas at 30°C. (48 hr.)	0	⟨3⟩ 12	— —	— 1	⟨3⟩ 13	⟨8⟩ 8
	<5	— 1	— —	⟨2⟩ —	⟨2⟩ 1	5 1
	10 or more	⟨1⟩ 47	— 22	⟨31⟩ 76	⟨32⟩ 145	⟨87⟩ 91
Total	No.	⟨4⟩ 60	22	⟨33⟩ 77	⟨37⟩ 159	—
	%	⟨11⟩ 38	— 14	⟨89⟩ 48	—	100

⟨No.⟩—Winter Series.
Others—Summer Series.
%—To nearest whole number.

correlation between season of isolation and the effect of temperature on gas production from standard lactose broth by isolated cultures suggests that the slow lactose fermenters encountered, being much more prevalent during the summer season, may be associated with soil washings.

Table 5, perhaps, shows in a simpler manner, the relation or correlation between season of isolation and characteristics of the isolated organisms with respect to the effect of temperature of incubation on their ability to produce gas in lactose broth. In this table the organisms are sub-divided into four groups: (A) those which produced

10 per cent or more gas at both 30°C. and 37°C.; (B) those which produced gas poorly at both 37°C. and 30°C.; (C) those which produced gas poorly at 37°C. but 10 per cent or more gas at 30°C.; and, (D) a small group comprising those which produced gas poorly at 30° and 10 per cent or more gas in 48 hours at 37°C.

Attention is called particularly to group C. It will be noted that only a single strain of the 37 cultures isolated during the winter fell into this group, whereas 67 (42 per cent) of the 159 summer strains were in this category. This group then accounted for a goodly proportion of the questionable presumptive tests encountered with the

TABLE 5

Season of Isolation and Rate of Gas Production from Standard Lactose Broth

ISOLATED DURING		SUMMER	WINTER	SUMMER	WINTER
Type	Gas (48 hr.)	Number of strains		Per Cent of strains*	
A	37°C. Good 30°C. Good	80	29	50	78
B	37°C. Poor 30°C. Poor	11	4	7	11
C	37°C. Poor 30°C. Good	67	1	42	3
D	37°C. Good 30°C. Poor	1	3	1	8
Total.....		159	37	100	100

* To nearest per cent.

Poor = No gas or less than 10 per cent in 48 hr.

Good = 10 per cent or more gas in 48 hr.

standard technic. The question as to the source and sanitary significance of these slow lactose fermenters is of paramount interest but that phase will not be discussed in this report which is restricted primarily to the characteristics of the isolated organisms. It does appear, however, that they are probably soil forms, possibly closely allied to some of the bacterial plant pathogens, at least with respect to their growth temperature relationships.

It is felt by some investigators that these slow lactose fermenters are of minor sanitary significance and might well be disregarded. Although this view is not considered tenable without considerable additional data as to their possible sanitary significance, it was

thought that it would be of interest to ascertain whether they could be eliminated by use of some of the various presumptive tests which have been suggested as substitutes for lactose broth. The strains of group C did not grow at 46°C. and the Eijkman test and its various modifications are therefore not considered at this time.

Gas Production of Coliform Strains

One hundred and ninety-two strains were inoculated lightly from 24 hr. 30°C. agar slant cultures into the various presumptive test media listed in table 6. Ninety-two of the 192 strains, in this ex-

TABLE 6

Gas in Presumptive Test Media

Gas in Lactose Broth 37°C. 48 hr.	less than 10%		10% or more	
No. of Strains	92		100	
Gas in other presumptive test media 37°C. 48 hr.	10% or More		Less than 10%	
Medium	No.	Per cent*	No.	Per cent*
Fuchsin Lactose Broth	27	29	17	17
Lauter and Dominick	44	48	13	13
Gentian Violet Lact. B	44	48	10	10
Brilliant Green Bile	50	54	6	6
Crystal Violet Lactose	51	55	10	10
MacConkey's Broth	52	57	12	12
Brilliant Green Bile (5 per cent)	52	57	9	9
Neutral Red	64	70	5	5
Formate-Ricinoleate Broth	71	77	6	6

* Per cent in round numbers.

periment, produced less than 10 per cent gas from the standard lactose broth in 48 hours at 37°C. Of these slow lactose fermenters 27 (29 per cent) produced 10 per cent or more gas in Fuchsin lactose broth and 44 to 52 strains (48 to 57 per cent) produced a goodly amount of gas in the following media: Lauter-Dominick medium, gentian violet lactose bile, brilliant green bile 2 per cent, brilliant green bile 5 per cent, crystal violet lactose broth and MacConkey's broth. With neutral red and the formate ricinoleate medium, 70 and 77 per cent, respectively, of the slow lactose broth fermenters produced large volumes of gas, generally over 20 per cent, at 37°C. in 48 hr. It is interesting therefore that these newer presumptive

test media tended to accelerate gas production in this group of organisms at 37°C.

Of the 100 strains which produced 10 per cent or more gas in lactose broth, the Fuchsin medium inhibited 17 per cent while in the 2 per cent bile, neutral red, and formate ricinoleate media only 5 per cent of the strains were inhibited.

If subsequent studies indicate the desirability of restricting or eliminating these slow lactose fermenters, then recourse to a higher temperature of incubation (possibly 43°C.) may be taken; but if it is desired to detect the maximum incidence of coliform organisms, it appears, from these data, that either the temperature of incubation of the presumptive lactose broth tubes should be lowered to approximately 30°C., or that some one of the more recently suggested presumptive test media such as brilliant green bile or formate ricinoleate at 37°C. may well be considered.

In this connection it might be pointed out that of the 12 lactose fermenting aerobic spore formers which were encountered in this study only 1 produced gas in gentian violet lactose bile, 2 in the 2 per cent brilliant green bile, 7 in the Lauter-Dominick and Fuchsin lactose media but none produced gas in 5 per cent brilliant green bile or in the formate ricinoleate medium.

Resistance of the Isolated Strains to Chlorination

In view of the fact that all of these strains were isolated from waters which had been chlorinated, and a large proportion of them from waters which showed residuals of over 0.4 p.p.m. (in many instances with contact periods of over 4 hours), it was anticipated that the strains might be chlorine resistant. Observations were made to ascertain the apparent resistance of the isolated strains of the coliform group to chlorination. The technic employed was briefly as follows. Suspensions of agar slant cultures (24 hr. at 30°C.) in buffered phosphate water at pH 7.0 (50 c.c. of M/15 K_2HPO_4 – KH_2PO_4 buffer mixture per liter of conductivity water) were prepared, so as to contain about 200,000,000 organisms per milliliter. Preliminary experiments indicated that the organisms survived in such a buffered water for several days and that the water did not exert a chlorine demand during the period of observation. One milliliter of the foregoing bacterial suspension was added to 100 ml. of the buffered water (pH 7) at 15°C., and the mixture thoroughly shaken. After standing in a water bath at 15°C., for about 5 minutes, chlorine

water was added to make a concentration of 0.4 p.p.m. available-chlorine and the number of surviving organisms and also residual chlorine (which was almost always 0.2 p.p.m.) determined after 20 minutes exposure.

Of the 37 winter strains 32 (86 per cent) showed no evidence of resistance to chlorine as indicated by the fact that over 99 per cent of the exposed bacteria were killed in 20 minutes when subjected to 0.4 p.p.m. (0.2 p.p.m. residual) available chlorine at 15°C. The remaining 5 strains showed less than 99 per cent kill, but in no instance, was the mortality below 75 per cent.

Considering 155 strains isolated during the summer, which were tested for chlorine resistance, it was observed that 110 (71 per cent)

TABLE 7

Apparent Resistance of Strains of Coli-aerogenes Group Isolated from Chlorinated Water

% KILLED*	UNDER 50	50-74	75-99	OVER 99	TOTAL
Coli-aerogenes type	Number of Strains				
Escherichia		4	4 (1)	11 (7)	19 (8)
Aerobacter	4	1	11 (2)	52 (13)	68 (15)
Intermediate	1	1	19 (2)	47 (12)	68 (14)
Total	5	6	34 (5)	110 (32)	155 (37)
Per cent	3	4	22 (14)	71 (86)	100

( ), Winter series; Others, Summer series.

* In 20 minutes at 15°C.; pH 7; 0.4 p.p.m. Cl_2 and 0.2 p.p.m. residual.

were definitely non-resistant (over 99 per cent killed); 34 strains showed mortalities of 75 to 99 per cent; with 6 strains, the mortality was 50 to 74 per cent; and 5 cultures showed less than 50 per cent killed. The extent to which the resistance to chlorination indicated by the foregoing preliminary observation may be attributed to clumps of bacteria has not as yet been ascertained and it should be borne in mind that some of these apparently resistant strains may be lactose fermenting spore formers of the genus *Aerobacillus*.

Assuming that results obtained in these preliminary studies will be confirmed by more carefully controlled experiments now in progress, the data indicate that resistant strains are more likely to be encountered during the summer, and particularly, that survival of the strains in the chlorinated waters was probably not due to an

inherent chlorine resistant character of the individual organisms under consideration but is much more probably associated with the presence of clumps or protection of the organisms against the action of chlorine by some constituent or characteristic of the water. The data indicate the desirability of further investigation into the meaning and significance of residual chlorine as an index of germicidal efficiency.

Organisms Other Than Coliform

The coli-aerogenes organisms accounted for 196 of the 282 strains considered in this report. The other strains were distributed as

TABLE 8

Organisms Isolated from Chlorinated Water

GENUS	WINTER SAMPLES	SUMMER SAMPLES	TOTAL
Escherichia	8	20	28
Aerobacter	15	70	85
Intermediate	14	69	83
Eberthella	1	7	8
Shigella	1	3	4
Salmonella	3	2	5
Proteus	0	18	18
Alcaligenes	0	2	2
Pseudomonas	15	2	17
Lactose + sporeformers	1	11	12
Miscellaneous	0	20	20
Total	58	224	282

indicated in table 8. Attention is called particularly to the fact that there were obtained 8 *Eberthella* from 6 samples of water, 4 *Shigella* from 2 samples of water and 5 *Salmonella* strains from 5 water samples. These organisms are now being studied to ascertain their relations to typical typhoid, dysentery and paratyphoid cultures, respectively. In no instance do these organisms agree absolutely with the well known pathogens on the basis of cultural characters, but one of the *Eberthella* strains agglutinated with a typhoid serum in a dilution of 1:1,000.

It is significant that non-spore forming bacteria of the typhoid-dysentery group were isolated from waters which were chlorinated and in which high residuals were maintained. Even though these forms are probably not identical with present known and recognized intestinal pathogens, it must be borne in mind that they may be indicative of the possible survival of such pathogens and it should not be forgotten that new hitherto unrecognized pathogenic species need be looked for. Their presence as well as the detection of coli-aerogenes strains in chlorinated water certainly indicates that dependence upon residual chlorine (0.2 to 0.4 p.p.m.) as now determined by the ortho-tolidine test is not a reliable index of the probable absence of non-spore forming members of the intestinal group of bacteria. A detailed and thorough investigation into the meaning and significance of residual chlorine under various conditions encountered in water treatment is warranted.

Summary

There were submitted for identification 162 cultures of bacteria isolated from 97 samples of water which had been chlorinated either with chlorine or ammonium sulfate and chlorine. Two hundred and eighty-two strains obtained by re-purification of the cultures submitted were studied in detail. Among these were included 196 strains of the coli-aerogenes group, 5 organisms belonged to the genus *Salmonella*, 4 to the genus *Shigella* and 8 to the genus *Eberthella*.

A striking characteristic of the coliform strains was the fact that a large proportion of those isolated during the summer, when the temperature of the water was 12° to 22°C., fermented standard lactose broth very slowly at 37°C., whereas gas production at 30°C. was quite satisfactory. However, these strains, for the most part, produced gas readily at 37°C. in many of the newer presumptive test media such as brilliant green bile and formate ricinoleate broth.

A large proportion (63.8 per cent) of coli-aerogenes strains obtained from chlorinated water was in the category of slow lactose fermenters on the basis of their gas producing properties at 37°C. Their sanitary significance is not definitely established but if it is desired to include them in the coliform index (and on the basis of present available data it is felt that they should be) their detection will be facilitated by either lowering the temperature of incubation for the

presumptive test to 30°C. or substituting such media as brilliant green bile or particularly formate ricinoleate broth.

Although there was some indication that apparently chlorine resistant colon strains were more likely to be encountered in chlorinated water during summer, the evidence, on the whole, indicated that survival of coli-aerogenes strains in chlorinated water is probably due to presence of clumps of bacteria or protection of the organisms by some constituent of the water, rather than to resistance of the individual bacteria themselves to the action of chlorine.

In view of the fact that non-spore forming members of coli-aerogenes, *Eberthella*, *Shigella*, *Salmonella* and other closely related genera, were isolated from waters which showed high chlorine residuals, even after contact periods of two to six hours, it appears that a chlorine residual of 0.2 to 0.4 p.p.m., as at present determined by ortho-tolidine, is, in itself, not a dependable criterion of adequate water sterilization.

Electro-Chemical Properties of Chlorinated Water

By F. C. Schmelkes, E. S. Horning and G. A. Campbell

IN THE majority of cases operation of a water plant which depends upon chlorination for bacterial control relies upon the validity of the ortho-tolidine test. This chemical test is the best that is available at the present time but its shortcomings are well known and are the main source of inadequate water sterilization. The errors inherent to the ortho-tolidine test are three fold:

1. As the reagent is made up with hydrochloric acid, small traces of oxidizing compounds, chiefly higher oxides of manganese, will oxidize the hydrochloric acid to chlorine and produce false residuals. This difficulty cannot be overcome by the use of a different acid, as most waters contain a sufficient amount of chloride ion to give a false residual.

2. If the water contains nitrite, a colored compound presumably due to diazotization, is developed when ortho-tolidine is added. This compound approximates in hue the color developed by chlorine.

3. Any chloramine formed in the water, not only the simple chloramines but also chloramines arising from the action of chlorine upon so-called albuminoid amino groups, is split into chlorine and ammonia compounds when the pH of the water is greatly lowered, as is the case when the acid ortho-tolidine reagent is added. As some of these more complex chloramines have little or no bactericidal power, a residual of higher bactericidal effect is indicated by the ortho-tolidine test in these cases.

Rideal and Evans in 1921 (1) suggested that the bactericidal power of chlorine compounds may be subject to similar variations as their oxidizing power, and suggested a device utilizing this principle. Some years ago one of us (2) drew the attention of workers in the

A paper presented on June 14, 1939 at the Atlantic City Convention by Dr. F. C. Schmelkes, Elizabeth S. Horning and George A. Campbell, Research Laboratory, Wallace & Tiernan Co., Inc., Belleville, New Jersey.

field to the possibilities of potential measurements as a means of evaluating the chlorine residual in water.

Any oxidizing agent is able to take up electrons, and any oxidation consists in the migration of electrons from some reducing agent to the oxidizing agent. If a noble metal electrode is dipped into an oxidizing solution, the oxidizing agent has the tendency to take up electrons from the noble metal and the intensity with which it is able to do so is indicated by the potential of the electrode. In other words a highly oxidizing solution will show a more positive potential when a noble metal electrode is dipped into it than will a less oxidizing solution. In certain special cases where the process is thermodynamically reversible, potentials can be read which have a special significance. These potentials are usually independent of the absolute concentration of the oxidizing and reducing agent in question and are dependent only upon their relative concentrations. Such potentials are the true oxidation reduction potentials and they find frequent use in physico-chemical investigations, for instance, as a means of measuring hydrogen ion concentration. The quinone hydro-quinone system is one of the most common examples of this type of oxidation reduction system.

In the range of pH values encountered in water works practice, the reaction which leads from chlorine through hypochlorite ion to chloride ion is not a reversible one. The electrode potential which can be measured in chlorinated water is, therefore, not a true oxidation reduction potential. In addition, unless carefully controlled conditions are maintained, definite and reproducible potentials cannot be established when noble metal electrodes are brought into contact with chlorinated water. In a solution of a substance which is highly reactive chemically, even a so-called noble metal electrode might not act altogether as an indifferent electrode. Such interaction between the substance and the electrode tends to affect the potential. When the solution is concentrated this effect can be neglected but when measuring chlorine solutions such as encountered in water works practice this is unfortunately not the case. It is, therefore, of great importance to so standardize conditions that this effect is a definite, reproducible one and electrode measurement can be made a useful tool (3).

It is the purpose of this paper to give a preliminary report of the methods we used, and of the extent to which the potentials we read can be correlated with chlorine concentration, pH, ammonia concentration, and bactericidal effect.

Apparatus Described

For reasons just stated more than usual care must be expended upon the design of apparatus to enable the laboratory worker to bring about constancy of experimental conditions.

One of the great difficulties in electrode measurements in flowing chlorinated water is the tendency of the electrode surface to become insensitive. This difficulty was overcome to a great extent by C. F.

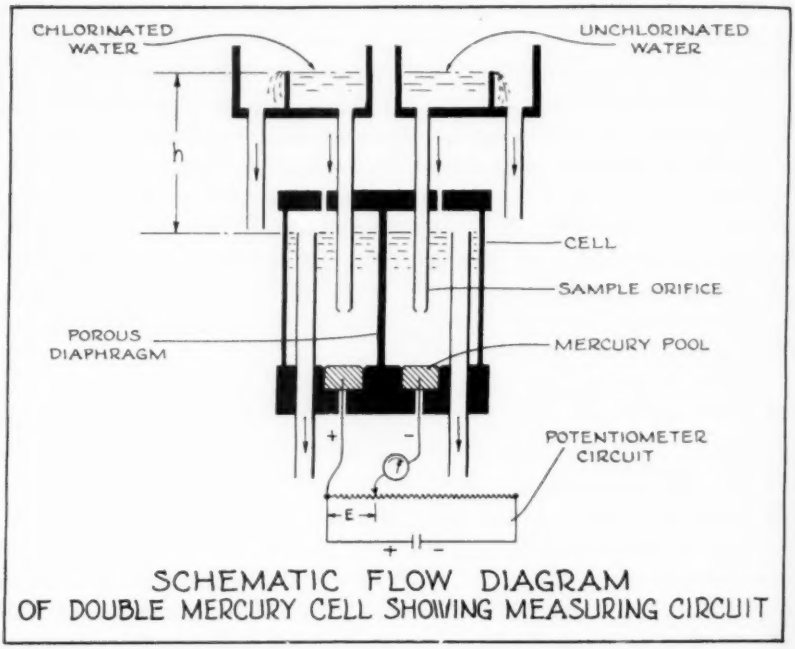

FIGURE 1

Wallace who designed an electrode using a pool of mercury and causing a stream of chlorinated water to impinge upon it. A noticeable ripple is thus produced upon the surface of the metal, exposing a continuously renewed sensitive mercury surface. In the apparatus shown in fig. 1 there are two of these electrodes, one operated with a stream of unchlorinated water and the other with a stream of chlorinated water. The two cells are so wired that their potentials oppose each other, and the differential potential between the two cells is read or recorded.

In this apparatus technical details are of surprisingly great influence. For instance, the velocity of the stream of water markedly affects the potential. As the velocity increases, the potential in each cell increases but the difference between the two potentials decreases. At high velocities the double cell becomes almost insensitive to minor additions of chlorine.

The inherent disadvantage of a mercury electrode is that mercury is not a truly noble metal. Mercury behaves like a noble metal only in potential ranges which are low on the conventional scale. In higher potential ranges prevailing in chlorinated water, the base metal character of the mercury begins to affect its usefulness as an electrode. For instance, under such circumstances the sensitivity of the mercury electrode may be adversely affected by the chloride ion content of the water.

When using the mercury electrode the electron donors in the oxidation process are mercury atoms. When they give up their electrons they go into solution and become oxidized to ions. In the presence of high chloride ion concentrations, the requirements of the mass law restrict the possible ion concentration and the electrode may become insensitive.

In low potential ranges, for example in the sub-residual range, however, this electrode is a sensitive instrument for controlling chlorination rates. In the chlorination of sewage it is frequently sufficient to add an amount of chlorine which will increase the stability of the sewage to the point where it can be handled for a relatively brief period without creating an odor nuisance. Heretofore, no device and certainly only the most cumbersome chemical methods have been available to determine sub-residual chlorine doses.

This device has also been advantageously applied to the chlorination of return sludge where partial chlorination of the return sludge may greatly improve settling conditions.

It is not always necessary to measure a differential potential by using two mercury electrodes. A single mercury electrode can be compared with a stable reference electrode, for instance a calomel electrode, and the total potential increase due to the addition of chlorine can serve as an adequate guide in controlling the operation.

Figure 2 is a diagram which represents a day's run in a sewage plant using a mercury electrode for controlling the chlorine feed. At this particular plant, prior to the installation of this equipment, chlorinators were operated at the rate of 55 pounds per 24 hours.

Since the installation of this equipment 43 per cent of the former chlorine dose is being saved.

While the compounds which are responsible for the potential increase in insufficiently chlorinated sewage are unknown and have not been investigated, they give indication of being of the thermody-

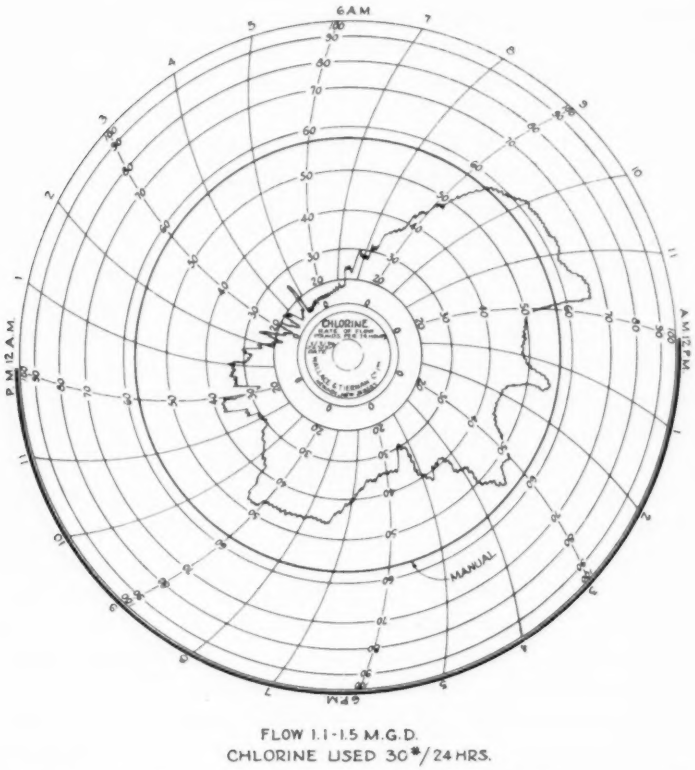

FIG. 2. Twenty-four-hour record of chlorine added to sewage. Irregular line indicates chlorine required to maintain even potential.

namically reversible type. The readings are much more easily established and much less dependent upon adventitious circumstances. If instead of a pool of mercury a gold plate is used for potential measurements, the potential increments indicated by the gold electrode are larger for the same chlorine residuals than those indicated by the mercury electrode. A comparison of these two relationships is given in fig. 3.

Effect of Chemical Composition upon Differential Potentials

The values plotted in fig. 4 show the variation encountered in tap water of different origin. The difference in the slope of the curves is due to variation of the concentration of hydrogen ion, ammonia, and chloride as well as other less known factors. In figs. 5, 6, and 7 the effect of chloride ion, hydrogen ion, and ammonia concentration respectively is studied in one tap water.

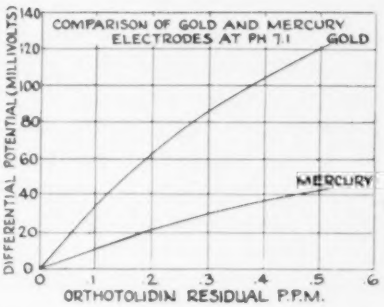

FIGURE 3

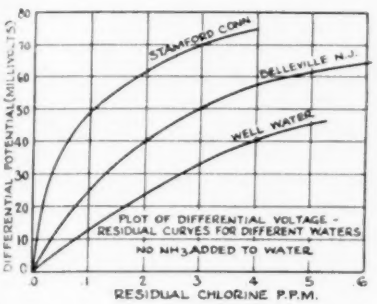

FIGURE 4

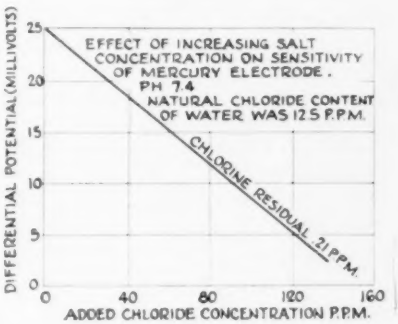
EFFECT OF INCREASING SALT CONCENTRATION ON SENSITIVITY OF MERCURY ELECTRODE.
PH 7.4
NATURAL CHLORIDE CONTENT OF WATER WAS 12.5 P.P.M.
CHLORINE RESIDUAL 21 P.P.M.
DIFFERENTIAL POTENTIAL (MILLIVOLTS)
ADDED CHLORIDE CONCENTRATION P.P.M.

FIGURE 5

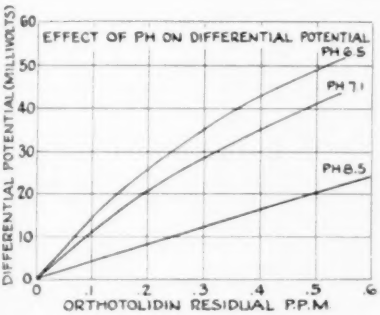

FIGURE 6

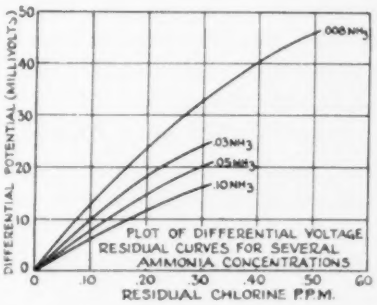

FIGURE 7

Another factor which is still under investigation is the influence of the value of the base potential of the unchlorinated water upon bactericidal efficiency of the chlorine residual. In waters to which chlorine has been added in such amounts that the same differential potential values are obtained, it makes a material difference whether chlorine is added to raise the potential from 170 mv in the unchlorinated water to 190 mv in the chlorinated water, or whether a corresponding change is obtained in water with a base potential of 190 mv. The degree to which the water is poised at its base potential is also probably of moment.

Potential Measurements and Bactericidal Effect of Chlorine Residuals

The following general method was used. The influence of chlorine alone, and of two different modes of chloramine treatment, was studied. In one case chlorine and ammonia were allowed to interact for a certain period of time before the solution came in contact with the organisms. In the other case chlorine was added to the flowing water which contained ammonia and the organisms. This is comparable to regular water works practice where the ammonia is added before the chlorine.

TABLE 1

Analysis of Well Water—Depth 568 feet, April 5, 1939

Temperature °C	15.6	Iron	0
Oxygen consumed	1.0	Chlorides	12.5
Dissolved oxygen	8.6	Carbon dioxide	16.0
Free ammonia	.008	Sodium	17.0
Albuminoid ammonia	.004	Magnesium	21.0
Nitrites	.000	Calcium	48.0
Nitrates	5.0	pH	7.5
Hardness	202	Manganese	.02
Alkalinity	120		

A well water supply substantially free from ammonia was found in an industrial establishment in Belleville, New Jersey. The water showed the analysis as given in table 1.

A 50-gallon glazed crock was used as a retention tank. Well water was pumped into the crock, and buffer, ammonia, and bacterial suspension were added as required. All the experiments shown in the subsequent figures were carried out at pH 7.1, phosphate buffer being used. The bacterial suspension was made from a strain of

Esch. coli carried in our laboratory for a long time. This strain showed evidence of having become fairly well stabilized. Using the typing system of Stuart (4) this strain can be characterized as belonging to type nineteen, a true *Esch. coli* giving the usual biochemical reactions for this group, as shown in table 2.

The suspension which was used has apparently a very fine resistance distribution and contains a relatively small percentage of individuals of either low or high resistance. In all the following experiments a washed suspension was used which was thrown down from a neopeptone broth culture; resuspended and centrifuged twice with distilled water. Throughout the many experiments the count in the crock varied between 40,000 and 80,000 per ml, with the majority of the tests varying between 50,000 and 60,000. With reference to the broth culture, this represented a dilution of one to ten thousand.

TABLE 2

Biochemical Reactions of Coli 9

PER CENT GAS LACTOSE 37° 24 AND 48 HOURS	INDOL	METHYL RED	VOGES PROSKAUER	CITRATE	CELLOBIOSE
40/40	+	+	−	−	−

Type 19, Group C, Stuart Chart.

It was found that the type of survival curve obtained with the three chlorination processes, namely, chlorine, preformed chloramine, and ammonia and chlorine added separately to a flowing stream of water showed significant differences as shown on fig. 8. The relation which can be inferred from them is of great interest. The survival curve for chlorine shows the rapid bactericidal effect characteristic for this agent. The preformed chloramine shows the extensive lag period which has been so often commented upon in previous investigations.

According to Reiner's (5) concept of the relation of toxicity, resistance and rate of survival, this lag period is undoubtedly due to the difference in the rate of adsorption of two compounds by the bacterial cell. It is an indication of the fact that mode of attack of the two agents upon the organism is essentially different.

The most interesting of these three curves, however, is the middle one. Its shape is in line with the chemical reaction between chlorine

and ammonia. The completion of this reaction requires an appreciable amount of time. The corresponding survival curve may be interpreted as showing that the bactericidal process follows during the first time interval the rapid killing due to chlorine followed shortly thereafter by the chloramine type of killing.

A large number of such time survival curves for all three types of agents are shown in figs. 9, 10, and 11. The data represented in these curves were obtained in the following manner:

Where no ammonia was used, the bacteria were suspended in the buffered water, the water permitted to flow to the cell and chlorinated in accordance with the diagram shown in fig. 12.

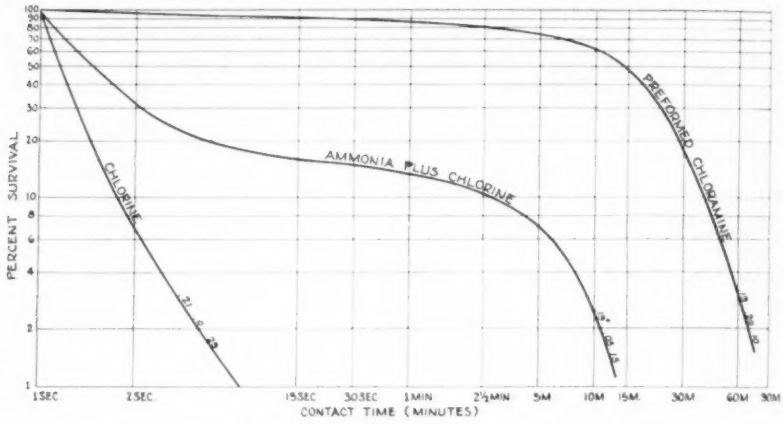

FIG. 8. Per cent—Survival—Contact Time of typical bactericidal curves for chlorine, chlorine-ammonia and preformed chloramine.

Just before it reached the cell a sample was withdrawn. At stated intervals measured amounts were removed from this sample, de-chlorinated, and plated. In the plots of survival rates in solutions where chlorine and ammonia were added separately, the samples were gathered in exactly the same way, except that in this experiment the water in the crock contained ammonia besides buffer and bacteria. Finally, in the experiment where preformed chloramine was investigated, chlorine was added to the crock of water containing ammonia and buffer. After a fifteen minute contact period, the water was permitted to flow to the cell. Immediately after reading the potential, a measured portion of the water was inoculated, well stirred, and from this measured amounts were withdrawn, de-

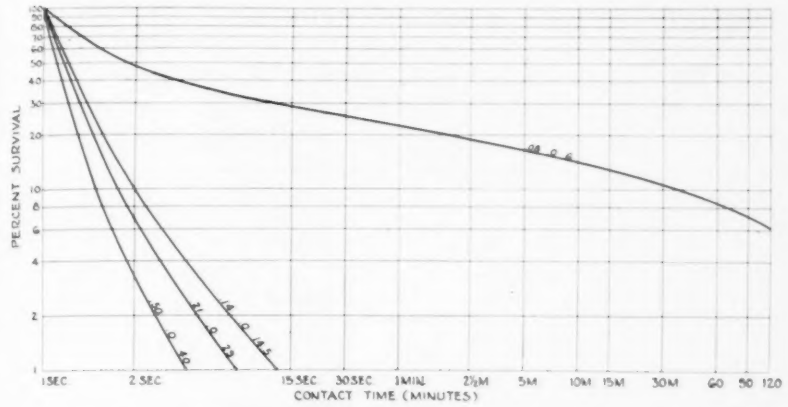

FIG. 9. Per cent Survival—Contact Time of Chlorine Treatment, temp. 13–14°C., pH 7.1. The figures on the curves reading from left to right indicate residual, ammonia added, and differential potential measured in each of those solutions. Particular attention should be drawn to the fact that in the curve representing the lowest residual, namely .08, a solution was tested which contained no added ammonia, but as the natural ammonia content of the water amounted to .008 parts per million, a definite effect upon the small chlorine dose is noticeable, and the curve approximates to some extent a chloramine type curve. The effect of this trace of ammonia is not noticeable in the curve representing higher chlorine residuals.

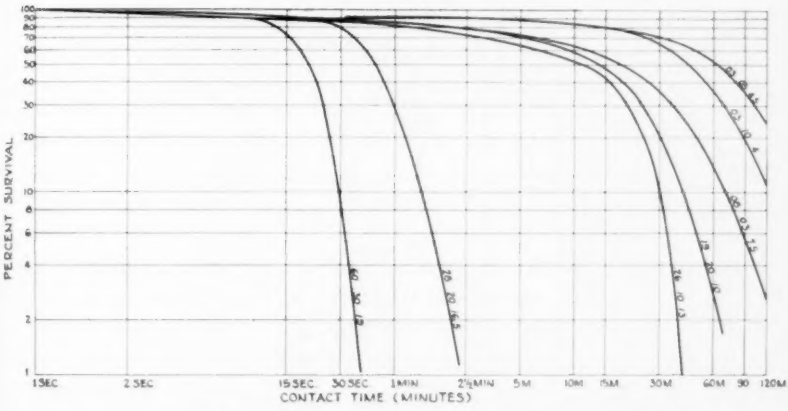

FIG. 10. Per cent Survival—Contact Time of Preformed Chloramines, Temp. 13–14°C., pH 21. The figures on the curves reading from left to right indicate residual, ammonia added, and differential potential measured in each of those solutions.

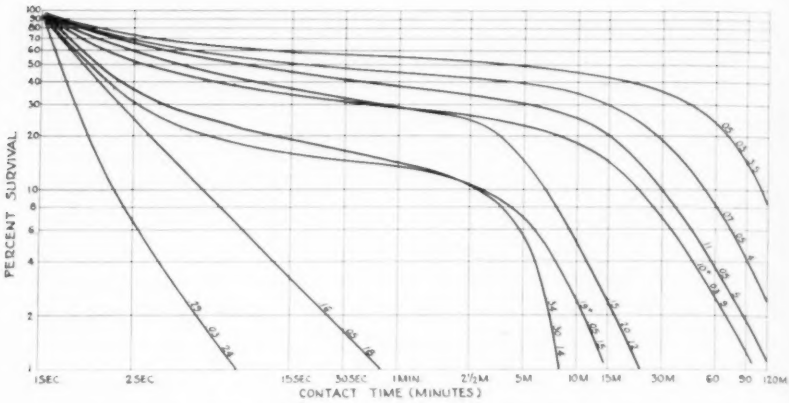

FIG. 11. Per Cent Survival—Contact Time of Chlorine-Ammonia Treatment, temp. 13–14°C., pH 7.1. The figures on the curves reading from left to right indicate residual, ammonia added, and differential potential measured in each of those solutions.

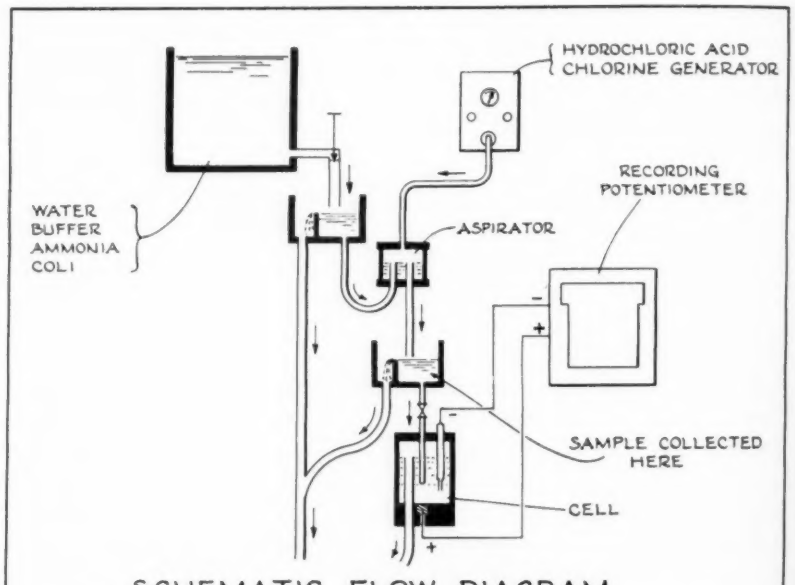

FIG. 12. Ammonia chlorine treatment. Chlorine added to water containing ammonia.

chlorinated at the stated intervals, and plated. A schematic flow diagram for this treatment is shown in fig. 13.

It is believed that the first two of these experiments, the ones with chlorine alone and chlorine and ammonia separately are the first instances where chlorination in the laboratory has been carried out in a flowing system and not by the batch method. As the effect indicated can be observed only if a number of points are determined

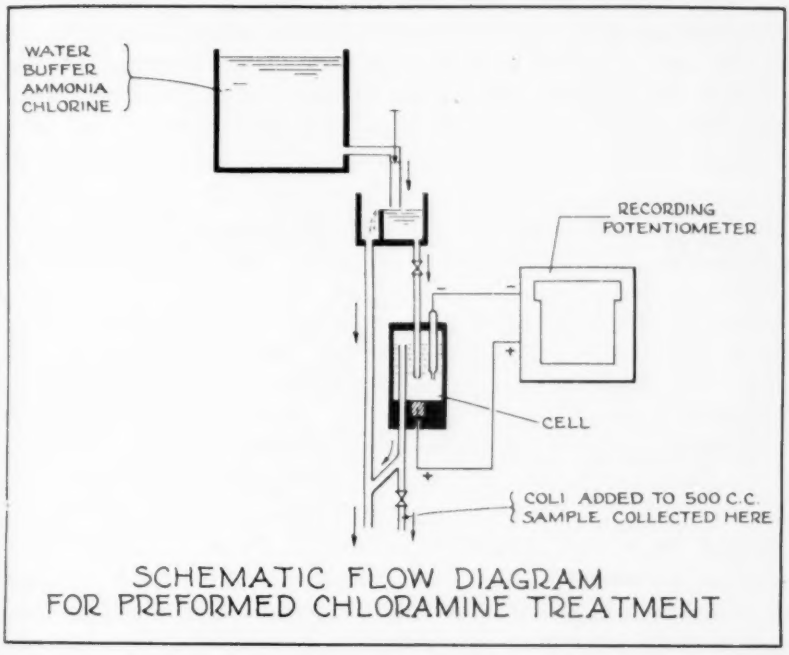

FIG. 13. Chloramine Treatment. Chloramine formation at equilibrium before contact with bacteria.

within the first short increments of time, it is not surprising that they have escaped the attention of other investigators.

An interesting comparison between these three methods of chlorination can be obtained by plotting the contact time required for different residuals and different potentials to reduce the original count to 50 per cent. It is realized that 50 per cent survival rates are normally not considered in connection with problems involving water supply quality because the main interest is in reducing the pathogen count to zero. For statistical reasons, however, a zero

survival is a very unsatisfactory region from which to draw conclusions because a few stray resistant organisms or a minor break in the technique, such as clumping or inadequate mixing, introduces a variation of such magnitude that no satisfactory relations can be established. These same considerations make it almost as difficult to draw curves with adequate accuracy for regions of 90 per cent or 80 per cent reduction.

The relation between potential and residual against contact time in the region of 50 per cent and 80 per cent survival is shown in fig. 14. It is obvious that there is very little difference between straight chlorination and chloramination. In the first short increment of time the effectiveness of chloramination is of high degree and so much like that of chlorine that the drop from 100

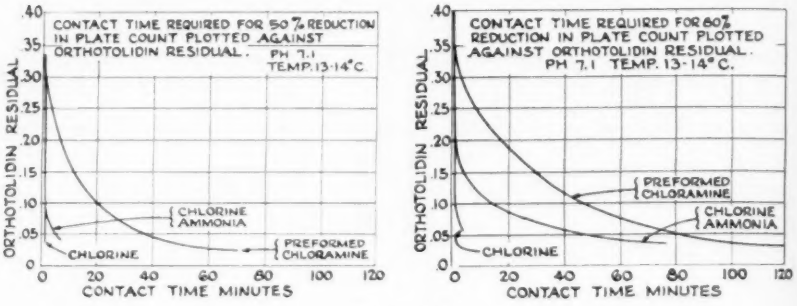
CONTACT TIME REQUIRED FOR 50% REDUCTION IN PLATE COUNT PLOTTED AGAINST ORTHOTOLIDIN RESIDUAL. PH 7.1 TEMP. 13-14°C.
ORTHOTOLIDIN RESIDUAL
CHLORINE AMMONIA
PREFORMED CHLORAMINE
CHLORINE
CONTACT TIME MINUTES
CONTACT TIME REQUIRED FOR 80% REDUCTION IN PLATE COUNT PLOTTED AGAINST ORTHOTOLIDIN RESIDUAL. PH 7.1 TEMP. 13-14°C.
ORTHOTOLIDIN RESIDUAL
PREFORMED CHLORAMINE
CHLORINE AMMONIA
CHLORINE
CONTACT TIME MINUTES

FIGURE 14

per cent to 50 per cent survival is effected with almost equal rapidity for both types of chlorination. If the chloramines are permitted to preform, however, rapid reduction to 50 per cent can only be obtained with very high dosages. For 80 per cent reduction longer intervals are necessary.

Here the reaction between chlorine and ammonia goes to completion. The statement that chlorination and ammonia chlorine addition are of similar effectiveness holds true only for higher dosages. The same applies if 90 per cent or 100 per cent curves are drawn. Some water plants, in changing from straight chlorination to chloramination, increase the chlorine dose considerably. It is our belief that if this precaution is maintained the water supply is actually much safer than it has been commonly assumed to be, and that the lag is much less a reality than has been feared. These observations

also lead us to believe and to emphasize that where taste prevention is not an actual problem, the addition of chlorine first and ammonia afterwards is a sounder procedure.

Another important fact can be noted by comparing the shape of the curves in fig. 14 which were drawn at constant survival. Very little difference is found in the reduction to 50 per cent survival provided a certain minimum voltage is exceeded, regardless of the type of chlorinating agent employed. Above this voltage, reduction is almost instantaneous. The same relation holds true at 80 per cent survival although the minimum voltage there, of necessity, is higher. Such a statement cannot be made if the residual is used as a criterion. Using the residual as a criterion instead of the potential, it was found that with preformed chloramine particularly this relation holds true only with very high residuals. It seems, therefore, that the potential measured in a chlorine solution is a more trustworthy indication of the bactericidal effect, regardless of the nature of the chlorinating agent.

This can be stated in another way. Particularly with preformed chloramines, the voltage increase corresponding to the residual increase tapers off at high residuals. This effect is the more pronounced the higher the ammonia doses. The voltage measurable in solutions of chlorine and ammonia or in preformed chloramine solution is an indication both of the residual and of the extent to which its effect is modified by the amount of ammonia present. Therefore, more reliance could be placed upon the establishment of a stable minimum voltage than on the establishment of a minimum residual.

The data available do not as yet indicate how conditions prevailing in one water plant can be translated by means of a simple calculation or diagram into conditions prevailing in any other water plant. Nevertheless it seems certain that the reliability of the sterilization process can be greatly enhanced by using potential measuring devices, because variations in pH which affect the bactericidal rate affect the potential; variations in the natural ammonia content of the water likewise affect the potential; and variations in the manganese residual, which may cause the water works operator to reduce chlorine dosage and thus may affect the reliability of the sterilization process, will not affect the potential.

Summary

Some of the considerations involved in the establishment and measurement of electrode potentials in chlorine solutions have been presented. The bactericidal effect of chlorine residuals can be correlated with potentials measurable in such solutions. The effect of pH, addition of ammonia, and salt concentrations has been investigated. Data have been presented which pertain to the difference in action of straight chlorination, addition of chlorine and ammonia, and of preformed chloramine. The merits of potential measurements as an indicator of the extent to which the effectiveness of a chlorine residual is modified by the chemical composition of the water has been pointed out. It is believed that operating difficulties caused by false or misinterpreted ortho-tolidine tests can be minimized if potential measurements are carried out in addition to residual tests. It was emphasized that when using potential measurements the safety factor of water works operation is enhanced due to the fact that in contrast to the ortho-tolidine residual method, the operator is fore-warned of changes in the chemical composition of the water that may affect the amount and the bactericidal effectiveness of the chlorine residual. The value of potential measurements gauging subresidual addition of chlorine to sewage has been established. Credit should be given to Ornstein (6) and Pomeroy (7) for their work utilizing this principle.

The data presented in this report are of preliminary character.

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Super-Chlorination Practice in North America

By Harry A. Faber

THERE are two significant reasons why the super-chlorination process of water treatment deserves to receive attention at the present time.

First, the super-chlorination process has been in continuous use at a sufficient number of water treatment plants to yield evidence that control of tastes and odors by this process may be accomplished with efficiency and with economy. When such evidence is available, it is certainly of interest to the water works profession. Second, there is an insistent demand for the production of water which will meet standards of bacterial quality even more rigid than those minimum standards adopted by the United States Treasury Department. The super-chlorination process offers one means of attaining a higher standard of bacterial purity in the finished water.

Development of Super-Chlorination

Twenty years ago, Sir Alexander Houston (1) of the London Metropolitan Water Board referred to the taste and odor destroying properties of chlorine. He is, apparently, the first to utilize chlorine for that purpose and to propose the terms super-chlorination and de-chlorination. In a later report (2) he describes several experiences with this type of treatment and states not only that the super-chlorination method is uniformly successful, but that the more chlorine added, the more certain is the absence of taste after de-chlorination.

In America, Howard (3) at Toronto, Canada, determined phenolic substances in the raw water to be the chief cause of objectionable tastes which developed when the water was chlorinated for disinfec-

A paper presented on June 15, 1939 at the Atlantic City Convention by Harry A. Faber, Research Chemist, The Chlorine Institute, Inc., New York, N.Y.

tion. A complete discussion of extensive laboratory studies on the elimination of tastes and odors from this source was given by Howard and Thompson (4) in 1926. Their studies demonstrated that tastes were intensified with slight increases in the chlorine dose, but that above certain amounts of added chlorine the taste disappeared leaving only a chlorinous taste and odor. The excess chlorine could then be removed by means of a de-chlorinating agent such as sulfur dioxide. Since these laboratory results were so encouraging, the super-chlorination and de-chlorination method as suggested by Houston was tried on a full plant scale.

The first application of this process was made on September 2 and was continued until September 12, 1926. During the period over 70 million gallons of water were treated daily with a chlorine dose between 0.6 p.p.m. and 1.0 p.p.m. The corresponding dose of sulfur dioxide varied from 0.275 p.p.m. to 0.625 p.p.m. Taste developed in another part of the supply which was not treated by this process and became very pronounced, resulting in complaints from consumers. Not a single complaint was recieved from consumers of the water treated by super- and de-chlorination. The untreated part of the supply, acting as a control, indicated that had the whole supply been treated in the usual manner with approximately 0.275 p.p.m. of chlorine, taste would have been general throughout the city. The process was operated continuously from September 28 until December 8 of that year, making a total of 84 days of application. When it was stopped, intensive tastes became general and Howard (5) reports that in 1927 city officials were satisfied as to the success of this method and provided funds for the necessary equipment to make its use continuous.

Chlorine Destruction of Tastes and Odors

It has been noted by Baylis (6) that most of the odoriphore groups (this is the name applied to certain chemical groups in the molecule of the aromatic compounds) are easily oxidized and decomposed by a fairly strong oxidizing agent. The liberation of nascent oxygen from water when chlorine is added and the combination of this oxygen with the taste and odor compounds is believed to be responsible for the action of chlorine in removing these compounds. There is the further possibility that chlorine may unite with certain organic compounds to form substitution products which do not produce objectionable tastes and odors.

Watzl (7) stated that oxybenzenes, naphthols, and anthracene derivatives—tar, creosote oil, and the like—after high chlorination give higher substituted aromatic derivatives which, as a rule, have either no smell or only a slight smell. High chlorination, and therefore the production of hypochlorous acid, has the property of breaking up the benzene nucleus of many isocyclic compounds which have one or more hydroxyl groups in their nuclei. He pointed out that it is difficult to analyze precisely the action of chlorine on the taste and odor substances in water because their chemical composition is for the most part not yet determined. Investigations were cited which show that high chlorination can completely decompose urea from human and animal wastes into nitrogen and carbon dioxide, that the so-called albuminoid nitrogen can be reduced to minute traces, and that other substances are almost completely oxidized. Substances of the indole and skatole groups derived from vegetable and animal waste products are also destroyed.

A number of typical tastes and odors are listed by Baylis (6) as being susceptible to elimination or reduction by super-chlorination treatment followed by de-chlorination: chloro, fishy, algae, grassy, decaying vegetation, chlorophenol, aldehol, and hydrogen sulfide.

Methods of De-Chlorination

Several methods of removing excess chlorine after super-chlorination treatment have proven to be entirely practical. The method selected will depend upon local conditions of installation or operation.

Sulfur dioxide, the de-chlorinating agent used in the largest number of municipal installations, is an article of commerce available in cylinders similar to the familiar chlorine container. Equipment almost identical to standard chlorinators is utilized in the measurement and application of this gas. It is readily soluble in water, forming sulfurous acid which reacts with excess chlorine as follows:

$$Cl_2 + H_2O \rightarrow HCl + HClO$$

$$SO_2 + H_2O \rightarrow H_2SO_3$$

$$H_2SO_3 + HClO \rightarrow H_2SO_4 + HCl$$

Theoretically the amount of sulfur dioxide required in this reaction is less than the amount of residual chlorine or, approximately, 0.9 to 1.0. Complete de-chlorination is not necessary, and the dose of sulfur dioxide may be regulated to leave any desired residual. In order

to effect complete de-chlorination in practice, a slight excess of sulfur dioxide is required. This is thought to be due to a partial oxidation of the sulfurous acid before it comes in contact with the residual chlorine. The de-chlorinating action of sulfur dioxide is a rapid one.

Granular activated carbon is another satisfactory de-chlorinating agent, and its use for this purpose has been thoroughly studied by Baylis (6). Most installations are of the pressure filter type, the granular carbon being supported by layers of gravel the same as is the case for sand filters. These units may be operated with either upward or downward flow, though pressure units are usually operated with a downward flow. Carbon reacts with excess chlorine as follows:

$$2Cl_2 + 2H_2O \rightarrow 2HCl + 2HClO$$

$$2HClO + C \rightarrow 2HCl + CO_2$$

Pure carbon is theoretically capable of removing about 11.8 times its own weight of residual chlorine. What part of the carbon in activated carbon is available for reaction is not known, but should 25 per cent be available it would still be an economical material for de-chlorination. Baylis has demonstrated that, since this is a direct chemical action, there is practically no limit to the amount of chlorine which might be removed from water by conversion to hydrochloric acid. Thus granular carbon units are able to de-chlorinate water irrespective of how widely the residual chlorine content may vary and to leave only a few hundredths parts per million in the finished water. Because granular carbon removes residual chlorine through a chemical reaction, it is effective for de-chlorination long after it has lost its capacity to adsorb tastes and odors. According to Behrman and Gustafson (8) the chemical reaction between chlorine and carbon is preceded by adsorption of the chlorine. Evidently the applied chlorine becomes concentrated in the pores of the carbon before reacting chemically. A low pH value favors conversion of the free chlorine to the chloride ion.

Sodium bisulfite has been in use for nine years as the de-chorinating agent at one plant. This material may be fed by means of a small dry feed machine but it has proven more satisfactory, at low rates of application, to dissolve the chemical and to feed it as a dilute solution. Sodium bisulfite is readily soluble and contains 65 per cent available sulfur dioxide. Pflanz (9) reports that, in practice, the required ratio of anhydrous sodium bisulfite to residual chlorine is 1.6 to 1.0 for complete de-chlorination.

Other chemicals could be used for de-chlorinating but perhaps none is as economical as those in use at present. For experimental or temporary application, sodium thiosulfate (photographer's hypo) may be the most readily available de-chlorinating agent. Its use for this purpose is described by Flentje (10). Considerable data on the use of Catarsit (essentially neutral calcium sulfite) as a filtering medium to remove residual chlorine has been made available by Adler (11). Bach (12) has proposed the use of a filter containing scrap magnesium metal for the removal of chlorine and carbon dioxide, but plant scale adoption of this process has never been reported.

Plants Using Super- and De-Chlorination

A survey of those water treatment plants at which super- and de-chlorination are employed as a part of the purification process supplies useful comparative data. It is apparent that the rules governing this practice are not rigid but, rather, that it may be adapted to function satisfactorily under a variety of different conditions. While there is wide diversity in methods of application, in types of tastes and odors and in characteristics of the water treated, the process is successful in each case. In most instances the process is applied in conjunction with other purification methods.

At Toronto, two separate filtration plants are in use, one a slow sand filter employing no coagulant and one a mechanical filter plant using alum as the coagulant. The super-chlorination dose is applied to filtered water in each plant and, after a contact period in the clear well, is delivered to a common pumping station where the mixed water is de-chlorinated as it is pumped to the distribution system. Because of the longer contact period at the slow sand filtration plant and because this type of filter is more effective in partial taste removal, a lower chlorine dose has proved to be adequate at this plant. Super-chlorination is not continuously required at these plants because of the variable occurrence of a taste problem. In 1938 this process was used during 189 days at the mechanical filtration plant and 192 days at the slow sand plant. An extension to the Toronto system, which will include a new 100 m.g.d. filtration plant of the rapid sand type, is under construction (13). Super-chlorination following filtration and de-chlorination after a minimum contact period of one hour and 20 minutes will be standard practice at this plant.

At Glencoe, alum and the super-chlorination dose are applied in

the mixing basin. The chlorine residual is maintained through the settling basins, filters, and clear water well before de-chlorination. With this long contact period, relatively low doses of chlorine have proved adequate (9). At South Fallsburg, alum, soda ash, and the super-chlorination dose are applied to the raw water. No coagulation or settling basins are provided, though it is realized that these would be desirable for improved operation (14). Filtration is through pressure type units and de-chlorination takes place by a second filtration through a Permutit pressure filter containing Nuchar granular activated carbon.

Six plants in the vicinity of Los Angeles use a super- and de-chlorination process for the treatment of well waters which contain hydrogen sulfide, and iron and sulfur bacteria. The process is used with filtration, employing ferric chloride as the coagulant, at two plants. Two of the other four plants include aeration, and all have sedimentation basins to provide necessary contact time. Operation of all plants is almost entirely automatic (15). At five of the plants chlorine is applied in proportion to the raw water pumped and sulfur dioxide is fed in proportion to the water sent to the distribution system. At one of the plants chlorination is automatic and de-chlorination is accomplished by means of final pumping through International Filter type granular carbon units containing Hydrodarco.

It is reported that a number of large municipal installations in Europe employ Norit granular activated carbon in pressure filter units for de-chlorination. These operate effectively at extremely high rates of flow and have been in use for several years.

Tabulation of Plant Data

Toronto, Canada. Mechanical Filtration Plant

Super- and de-chlorination started: 1926
Source of water: Lake Ontario
M.G. per day treated: Average 38.76 (Imperial)
Type of taste and odor: Largely phenolic
Point of chlorine application: Following filtration
Chlorine dose: 16 to 42 pounds per m.g. (Imperial)
Length of contact time: 60 minutes
Residual prior to de-chlorinating: 0.7 to 2.0 p.p.m.
De-chlorination by means of: Sulfur dioxide
Point of de-chlorination: Pumping station to distribution system

Toronto, Canada. Slow Sand Filter Plant

Super- and de-chlorination started: 1926
Source of water: Lake Ontario
M.G. per day treated: 35.36 (Imperial)
Type of taste and odor: Largely phenolic
Point of chlorine application: Following filtration
Chlorine dose: 14 to 28 pounds per m.g. (Imperial)
Length of contact time: 3.25 hours
Residual prior to de-chlorinating: 0.7 to 2.0 p.p.m.
De-chlorination by means of: Sulfur dioxide
Point of de-chlorination: Pumping station to distribution system

Glencoe, Ill.

Super- and de-chlorination started: 1930
Source of water: Lake Michigan
M.G. per day treated: 1.0 average to 3.5 maximum
Type of taste and odor: Fishy, muddy, musty, cucumber, aromatic; generally due to plankton
Point of chlorine application: Mixing basin
Chlorine dose: 8.0 to 30 pounds per m.g.
Length of contact time: Minimum 3 hr., average 12 hr.
Residual prior to de-chlorinating: Minimum 0.8 p.p.m.
De-chlorination by means of: Sodium bisulfite
Point of de-chlorination: Effluent of clear water well

Culver City, Calif., Sentney Plant

Super- and de-chlorination started: 1933
Source of water: Wells
M.G. per day treated: 2.5 (plant capacity)
Type of taste and odor: Hydrogen sulfide, methane, those produced by iron and sulfur bacteria
Point of chlorine application: Following aeration
Chlorine dose: 25 to 42 pounds per m.g.
Length of contact time: Minimum 4 hr., Maximum 6 hr.
Residual prior to de-chlorinating: 0.35 p.p.m.
De-chlorination by means of: Granular activated carbon
Point of de-chlorination: Following filtration

Venice, California, Charnock Plant

Super- and de-chlorination started: 1933
Source of water: Wells
M.G. per day treated: 4.0 (plant capacity)
Type of taste and odor: Those produced by iron and sulfur bacteria
Point of chlorine application: Well water collection line
Chlorine dose: 20 to 40 pounds per m.g.
Length of contact time: Minimum 1 hr., Maximum 2 hr.
Residual prior to de-chlorinating: 0.35 p.p.m.
De-chlorination by means of: Sulfur dioxide
Point of de-chlorination: As pumped to distribution system

Lennox, Calif., Truro Plant

Super- and de-chlorination started: 1934
Source of water: Wells
M.G. per day treated: 2.0 (plant capacity)
Type of taste and odor: Hydrogen sulfide and those produced by iron and sulfur bacteria
Point of chlorine application: Following aeration
Chlorine dose: 40 to 58 pounds per m.g.
Length of contact time: Minimum 3 hr., Maximum 7 hr.
Residual prior to de-chlorinating: 0.35 p.p.m.
De-chlorination by means of: Sulfur dioxide
Point of de-chlorination: As pumped to distribution system

Culver City, Calif., Sepulveda Plant

Super- and de-chlorination started: 1935
Source of water: Wells
M.G. per day treated: 1.5 (plant capacity)
Type of taste and odor: Those produced by iron and sulfur bacteria
Point of chlorine application: Well water collection line
Chlorine dose: 16 to 25 pounds per m.g.
Length of contact time: Minimum 20 min., Maximum 2 hr.
Residual prior to de-chlorinating: 0.35 p.p.m.
De-chlorination by means of: Sulfur dioxide
Point of de-chlorination: As pumped to distribution system

South Fallsburg, N. Y.

Super- and de-chlorination started: 1936
Source of water: Surface supply, shallow lake
M.G. per day treated: Maximum 0.2 (estimated)
Type of taste and odor: Algae, swampy, muddy
Point of chlorine application: Pump suction to filter
Chlorine dose: 16 to 50 pounds per m.g.
Length of contact time: Maximum 10 min.
Residual prior to de-chlorinating: 0.5 p.p.m.
De-chlorination by means of: Granular activated carbon
Point of de-chlorination: Following filtration

Lawndale, Calif., Rosecrans Plant

Super- and de-chlorination started: 1937
Source of water: Wells
M.G. per day treated: 1.0 plant capacity
Type of taste and odor: Hydrogen sulfide, methane, those produced by iron and sulfur bacteria
Point of chlorine application: Following aeration
Chlorine dose: 8 to 16 pounds per m.g.
Length of contact time: Minimum 2 hr., Maximum 4 hr.
Residual prior to de-chlorinating: 0.35 p.p.m.
De-chlorination by means of: Sulfur dioxide
Point of de-chlorination: As pumped to distribution system

South Los Angeles, Calif., Normandy Plant

Super- and de-chlorination started: 1938
Source of water: Wells
M.G. per day treated: 1.0 (plant capacity)
Type of taste and odor: Hydrogen sulfide, those produced by iron and sulfur bacteria
Point of chlorine application: Following aeration
Chlorine dose: 20 to 25 pounds per m.g.
Length of contact time: 2 hr.
Residual prior to de-chlorinating: 0.35 p.p.m.
De-chlorination by means of: Sulfur ioxide
Point of de-chlorination: As pumped to elevated storage

Tyler, Texas

Super-chlorination treatment started: April, 1938
Source of water: Shallow lake
M.G. per day treated: Approx. 1.0
Type of taste and odor: Algae, decomposing vegetation, and decaying trees
Point of chlorine application: Mixing basin
Chlorine dose: Maximum 16 lb. per m.g. in winter; 58 lb. in summer
Length of contact time: Approximately 4 hr.
Residual prior to filtration: 0.8 to 1.0 p.p.m.
De-chlorination: None. Natural loss of residual
Residual in distribution system: 0.1 to 0.3 p.p.m.

Temporary Treatment for Tastes and Odors

There are a number of reported instances in which super-chlorination followed by de-chlorination has been applied for the correction of temporary taste and odor conditions. In 1929-30 Hale (16) successfully utilized such treatment for the destruction of a medicinal taste in water from a series of wells at Jamaica, N. Y. Despite the short contact period available and lack of technical supervision, this treatment proved to be very satisfactory. At Oklahoma City, Oklahoma, when taste and odor troubles from algae are at the maximum during summer periods, Scott (17) has found super-chlorination followed by de-chlorination to be an entirely practical method of control. The raw water is treated with high doses of chlorine and sulfur dioxide is applied by means of vacuum chlorinators for de-chlorination. Brown (18) has made a thorough study of methods for destroying growths of iron bacteria in water supplies. He reports super-chlorination followed by de-chlorination to be the most satisfactory method, and describes the use of this process in one reservoir. It is probable that a much wider use has been made of super- and de-chlorination than is revealed by published accounts.

Super-Chlorination Without De-Chlorination

There are many conditions under which it may be possible to apply super-chlorination doses and to so reduce the remaining residual chlorine that application of a de-chlorinating agent as such becomes unnecessary. The most simple of such methods would, of course,

be to allow the treated water to stand for a long period of time. If water is exposed to sunlight the loss of chlorine is particularly rapid due to photochemical action. Just such a method has been in successful use for over one year by Lloyd (19) at Tyler, Texas. He has learned that the maintenance of a chlorine residual of 0.8 to 1.0 p.p.m. in coagulated and settled water as applied to filters adequately controls tastes and odors. Treatment includes aeration, coagulation with alum, and the use of lime for pH adjustment. Residual chlorine in the distribution system varies from 0.1 to 0.3 p.p.m. See Tyler data on preceding page.

Under other conditions, there may be such a relatively low chlorine residual remaining after super-chlorination that addition of ammonia as the water enters the distribution system would adequately control chlorinous tastes. Considering residuals remaining in the water before de-chlorination at those plants which now employ super-chlorination, it would appear that frequently only the addition of ammonia might be required to produce a satisfactory water. If a chlorine to ammonia ratio of 2 or 3 to 1 proved suitable for this purpose, the use of ammonia would be no higher in cost than sulfur dioxide, and would at the same time result in carrying a persistent residual into the distribution system.

It should be possible to de-chlorinate with copperas (ferrous sulfate) when using copperas and lime for coagulation. The residual chlorine, after super-chlorination, would partially oxidize the ferrous iron and assist subsequent flocculation with lime.

At Pittsburg, Calif., Cook (20) has utilized a combination of aeration and super-chlorination to destroy tastes and odors due to hydrogen sulfide and the dose is adjusted so that, in combination with aeration, both iron and hydrogen sulfide are precipitated. By carrying little excess chlorine on to the filters, the precipitated iron is not redissolved and is utilized as the coagulant. Cox (21) reports a similar removal of residual hydrogen sulfide after aeration at Holland, N. Y.

Experiences with the effective use of chlorine for control and destruction of algae have been frequently reported. Usually the required dosage was higher than that required for disinfection, but not so high as to require de-chlorination. Details of such treatment have been published by Brush (22), Cohen (23), Bakke (24), Mangun (25) and a complete summary of this practice by Hale (26).

Super- and De-Chlorination in Industry

High doses of chlorine, sufficient to produce a residual of 3.0 to 4.0 p.p.m. before filtration are used (27) industrially for treatment of process water. The International Filter Company has made several hundred installations of this type. They involve either lime softening or coagulation and sedimentation plants followed by pressure sand filters with final de-chlorination by means of a pressure filter unit containing granular Hydrodarco activated carbon. Chlorine is fed, on conjunction with other treating chemicals, in the form of hypochlorite and a minimum contact period of 2 hours is provided. Ordinarily a 20-inch deep bed of the activated carbon gives a rated capacity of 2 gal. per sq.ft. per min., and with a 30-inch depth of bed the rate is increased to 3 gallons. In these installations sterile water, free from tastes and odors, is delivered without close chemical control. The treatment has proven very satisfactory in carbonated beverage plants, ice plants, and food processing plants. A large number of similar units have been installed (28) by the Permutit Company. These operate at the same rates and provide de-chlorination by means of pressure activated carbon filter units containing granular Nuchar. Both the completeness of such a treatment process and the simplicity of control have been responsible for its widespread adoption in industry.

Houston (2) appears to have derived the term super-chlorination from his reference to the use of "superdoses" of chlorine. The process has been defined (21) as: "The use of such high doses as to require the subsequent use of a de-chlorinating agent." This is, perhaps, the generally accepted understanding of the super-chlorination process. But, according to such a definition, a dose of chlorine sufficiently high to require de-chlorination may be applied to water and yet produce no oxidation. The dose may serve only to intensify the tastes and odors, leading to the conclusion that the process is unsatisfactory or not applicable to the particular water.

The fallacy of determining the efficiency of disinfection by the number of parts per million chlorine added has long been recognized. It has been learned that the proper criterion of disinfection is the measurement of residual chlorine after a definite contact period. In the same manner, the addition of higher doses of chlorine is no indication that adequate oxidation of organic matter will follow. The proper procedure to determine the effectiveness of a super-chlorina-

tion dose may again be to utilize a definite residual of chlorine after a definite period of contact. Just as a chlorine dose which is adequate for the disinfection of one water will prove inadequate in a different water, a super-chlorination dose for one water will not be a super-chlorination dose in a different water.

A number of authors have demonstrated that the dose of chlorine required for oxidation of tastes and odors will depend not only upon the type and intensity of those tastes and odors, but upon the length of contact time and upon the temperature of the water. The dose of chlorine will vary in some inverse relation to the length of contact time. The reaction proceeds with greater rapidity as the temperature of the water increases. It will be noted that the chlorine dose which, apparently, produces adequate oxidation in those plants which have used a super-chlorination process for a period of years varies from a minimum of 8 pounds to a maximum of 60 pounds per million gallons. The other important factor, contact time, is shown to range from 10 minutes to 12 hours.

It is recommended by Baylis (6) that application of chlorine for the super-chlorination process be made, wherever possible, to water in the mixing basin in order to provide the maximum contact time. Sometimes it is not possible to do this because the residual applied to filters will react with organic matter which has accumulated in the filter beds and produce objectionable chlorosubstitution products. In most instances this difficulty will be of short duration at the beginning of the process and should not recur if the treatment is continued. He experienced no trouble with filter beds increasing the taste in water at the Chicago Experimental Filtration Plant by the continuous use of the super-chlorination treatment.

Howard (4) reports laboratory experiments which show the intensity of taste in Toronto water to increase gradually with corresponding increases in the dose of chlorine. After a maximum taste is produced and the dose of chlorine is further increased, nothing is apparent but a strong chlorine taste. Upon de-chlorinating the samples, those which had received sufficiently high doses to taste only of chlorine were found to be entirely without taste. Those samples receiving lower doses of chlorine still possessed the objectionable taste. The series of experiments is illustrated graphically in fig. 1.

A set of experiments by Harrison (29) gives data on the production of tastes when increasing doses of chlorine are added to a solution

containing 0.075 p.p.m. of phenol. Chlorophenol tastes made their appearance with 0.125 p.p.m. of chlorine, disappeared at 0.5 p.p.m., reappeared with 0.8 p.p.m. and disappeared entirely at 1.0 p.p.m. Any further increase in chlorine had no effect and no tastes reappeared after standing for 24 hours. The results of these experiments are shown graphically in fig. 2. He also presents laboratory data showing that waste from gas works and waste from wood distillation plants (each diluted 1:10,000) could be rendered tasteless by the addition of 1.2 p.p.m. and 1.0 p.p.m. chlorine, respectively. Following these experiments, Harrison (30) tried super-chlorination on a plant scale, applying doses of 2.69 p.p.m. for about 3 months and for two days a maximum dose of 3.88 p.p.m. The results were highly disappointing since, in addition to intensified chlorophenol tastes, nauseating side tastes were experienced. Despite evidence from laboratory tests that the typical tastes could be oxidized with an adequate dose of chlorine it appears that a sufficiently high dose was not applied in the plant scale tests. This is apparent from a statement that the organic content of this water increases during taste periods. A second reason for the failure of this process on a plant scale is likely due to the fact that the chlorine was applied to the raw water and the sulfur dioxide, used for de-chlorination, was not applied until passage of the chlorinated water through the filters. Since the filter beds contained additional organic and phenolic material, it seems entirely probable that the residual chlorine passing though the filters was inadequate for oxidizing this additional material and acted to form tastes more intense than before. This is apparently an instance of high chlorination improperly termed super-chlorination.

Billings (31) at Grand Rapids, Mich., reported the application of a high chlorine dose, applying up to 2 p.p.m. to the surface of five filters which were producing a taste in the water. The chlorinous tastes were said to increase in proportion to the amount of chlorine fed. Obviously the term super-chlorination was improperly applied when considering the dose and conditions described at this plant. Gibbons (32) describes the plant scale use at Rahway, N. J., of chlorine doses from 1.0 to 2.6 p.p.m. with a contact period of 2 hours, at intervals which totaled over 200 days. Marked medicinal, woody, and chemical tastes were present in the water and varied widely in concentration from day to day. When chemical pollution was not excessive, the higher dosage of chlorine aided in preventing a medicinal taste in the supply, but in general there was little benefit

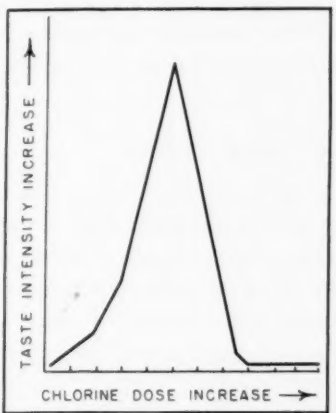

FIGURE 1. CHLOROPHENOL TASTE FORMATION AT TORONTO

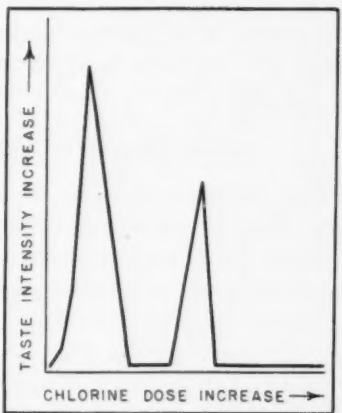

FIGURE 2. CHLOROPHENOL TASTE FORMATION AT BAY CITY

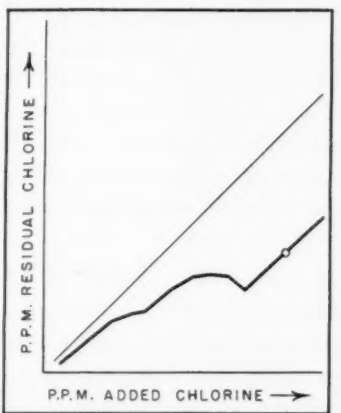

FIGURE 3. TYPICAL CHLORINE RESIDUALS WITH HIGH DOSES

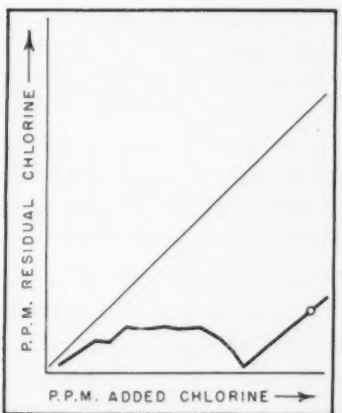

FIGURE 4. TYPICAL CHLORINE RESIDUALS WITH HIGH DOSES

Again it is apparent that the dose of chlorine applied was insufficient to accomplish oxidation in such a heavily polluted water.

Cox (33) found in laboratory studies that chlorophenol tastes in water at Buffalo, N. Y., could be destroyed by chlorine doses of 1.0 to 2.5 p.p.m. and that the water had no chlorophenol taste when de-chlorinated. Plant facilities did not permit full scale application of the process.

Determination of Super-Chlorination Dose

It has appeared desirable that a method be developed of determining the dose of chlorine which would insure oxidation of tastes and odors. When gradual increments of chlorine are added to a series of water samples, it has been found, as would be expected, that the amount of absorbed chlorine increased with increased doses. But the rate of absorption or reaction of the chlorine is not directly proportional to the dose in any water which has been tested. Instead, the residual changes in an erratic curve as shown in fig. 3. It is believed that an increase in the rate of residual absorption or chlorine reaction is due to the oxidation of various substances occurring at different chlorine concentrations or potentials. In highly polluted waters it has been found that the chlorine residual may be materially less with higher doses of chlorine than that existing with lower doses. This condition is illustrated in fig. 4. Instances have even been found in which the chlorine residual, after adding a high dose, will become practically zero or a trace too small to measure. Therefore, it appears that a distinction must be made between the chlorine "disinfection" demand of water and the chlorine "oxidation" demand of a water.

It is proposed that such a series of samples be run on a given water when it is desired to determine the effect of super-chlorination. In all the waters so far tested, oxidation of tastes and odors has been complete when the residual curve rises progressively with progressive increases in added chlorine. Since there may be several points on the residual curve at which the same residual will be found, but at which it is apparent the degree of reaction or oxidation is different, the safest procedure will be to select that point so high on the curve that above it only higher residuals exist. It is probable that this residual would insure complete oxidation at all times. Such a point is illustrated by the dot on each of the two typical curves shown.

Disinfection by Super-Chlorination

It is almost unnecessary to indicate that higher doses of chlorine are most effective in accomplishing greater bacterial kills. Low chlorine doses produce the greatest amount of disinfection per pound of chlorine, but the more resistant types of microorganisms often remain viable and may be unaffected until an oxidizing dose of chlorine is added. If super-chlorination can thus reduce the bacterial load in filtration plants and can insure the production of water of a high degree of bacterial purity in addition to the destruction of tastes and odors, this is a secondary advantage of very real importance.

Baylis (34) found in laboratory studies that the 37 degree count of a sewage plant effluent which contained from 6,700 to 20,000 bacteria per c.c. could be reduced to zero per c.c., using a process of

TABLE 1

Average Bacteriological Results for 1938, Filtration Plants, Toronto, Canada

	TOTAL COLONIES PER C.C., 37°C.		COLI-AEROGENES, PER C.C., 37°C.	
	Raw Water	Finished Water	Raw Water	Finished Water
Mechanical filter plant	1861	0.72	81.32	0.00017
Slow Sand filter plant	4071	0.72	106.69	0.00017

NOTE: Water is super-chlorinated after filtration at each plant but mixes before de-chlorination. Quality of the finished water is, therefore, of the mixture.

super-chlorination followed by de-chlorination. Under actual operating conditions at the Toronto plants, Howard reports the results given in table 1 which illustrate the effectiveness of this process on a highly polluted water.

Summary

The super-chlorination process has been demonstrated, at those water treatment plants where it has been standard operating practice for a period of years, to offer an effective means of taste and odor control. The destruction of tastes and odors due to algae, decaying vegetation, phenols, hydrogen sulfide, iron and sulfur bacteria, is entirely possible. The doses of chlorine required for this prupose are not excessive when compared with the cost of other methods of taste and odor removal. Under some conditions the cost of taste and odor removal by the process may even be less. Many plants using rela-

tively high doses of chlorine for disinfection are approaching super-chlorination doses and need relatively little increase to make it effective. It may be found that the cost of additional chlorine required to accomplish oxidation would provide the most economical means of taste and odor control. Both sulfur dioxide and granular activated carbon have proved to be economical de-chlorinating agents. Both methods are applicable to plants of any size and may be made practically automatic in operation. A secondary advantage of using super-chlorination is the high degree of bactericidal efficiency of such a process. This, too, has been demonstrated by both laboratory and plant results. In certain instances where the process has been tried without success, explanations of possible reasons for this condition are advanced. A method is proposed for laboratory control which will indicate the degree of residual necessary to assure oxidation of a given water at a given time. It is suggested that the consistent use of this method to control plant operation will indicate the dose of chlorine necessary to accomplish effective super-chlorination.

The author desires to give full credit to those who have so generously contributed the necessary data concerning super-chlorination and de-chlorination practice, and in particular to: L. J. Alexander, Southern California Water Co.; J. R. Baylis, Experimental Filtration Plant, Chicago; O. A. DeCelle, International Filter Co.; N. J. Howard, Toronto, Canada; J. M. Lloyd, Tyler, Texas; E. L. Pflanz, Glencoe, Illinois; and E. P. Schinman, Permutit Company.

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Discussion by *Charles R. Cox.* * The review of super-chlorination practice by Mr. Faber is very timely because this treatment procedure has been neglected since first being developed by Sir Alexander Houston at London, England, and then introduced on this side of the Atlantic by Norman J. Howard, Toronto, Ontario. It is suspected that this neglect is due to several practical factors, namely, the limitation in capacity of many existing chlorinators at filtration plants, and secondly, to the fear on the part of water works operators of chlorinous tastes which they deem would be more serious than those being controlled. For this reason taste control treatment has been restricted primarily to the application of ammonia in conjunction with chlorine or to the application of activated carbon. The growing emphasis placed upon more effective bacterial removal, however, is focusing attention upon the use of higher and more definitely effective doses of chlorine, whereby other benefits also are secured.

Chlorinators of ample capacity are inexpensive as compared to filtration plants and so super-chlorination is an economical way of obtaining increased degree of treatment. A realization of the practical aspects of de-chlorination, and also the expression of super-chlorination doses in terms of pounds per million gallons, or grains per gallon, as with other chemicals used in larger quantities than even super-chlorine doses, should tend to dispel any hesitancy in adopting super-chlorination.

Special emphasis should be given the statement by Mr. Faber that the term "super-chlorination" be restricted to the use of chlorine doses which are high in relationship to the chlorine demand of the water treated, thereby producing high concentrations of residual chlorine, which must be subsequently removed by some de-chlorinating agent. This is in contrast to the application of high doses of chlorine to certain waters which have an unusually high chlorine demand, thereby producing the conventional concentrations of residual chlorine. For instance, the raw water of a certain supply in New York State is treated with doses varying between 2.0 p.p.m. and 6.0 p.p.m. to secure residuals of 0.15 p.p.m. to 0.50 p.p.m. in the applied water after a reaction period of about 1.5 hours, which residual is removed by activated carbon accumulating on the filter beds. While these high chlorine doses are necessary and beneficial, the indications are that the residual chlorine content is below that

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required for major chemical changes. In other words, super-chlorination consists in the application of high doses of chlorine to secure correspondingly high concentrations of residual chlorine, which in turn result in chemical actions differing in character from those secured by conventional chlorination.

Reference is made to a paper by this discussor entitled "The Prevention of Chloro-phenol Tastes in New York State" (Jour. A. W. W. A., **21**: 1693 (1929)), in which laboratory experiments at Buffalo with super-chlorination and other methods of taste control were reviewed. In general, it was found that doses of chlorine up to about 1 p.p.m. greatly intensified tastes imparted by 0.1 p.p.m. phenolic compounds in the *raw* water, but that a dose of 3.0 p.p.m. altered these compounds and produced a tasteless water following dechlorination. The same water after coagulation and filtration could be freed of the tastes due to 0.1 p.p.m. phenolic compounds by doses of 1.5 p.p.m. chlorine, because of the lower chlorine demand of the filtered water. These experiments also indicated the importance of providing a minimum reaction period of several hours. Super-chlorination could not be applied at Buffalo on a plant scale during the short period when phenolic tastes were prevalent because of inadequate chlorinator capacity.

Emphasis should be placed upon one very important advantage of super-chlorination of water; namely, that frequent changes in chemical doses are not needed to maintain an adequate even though not uniform concentration of residual chlorine in the treated water, and at the same time of delivering water containing no residual chlorine. Therefore, super-chlorination with doses of chlorine meeting maximum requirements, followed by an adequate contact period and then by de-chlorination, constitutes one of the most attractive methods of treating seriously polluted water supplies of small size where adequate chemical control is lacking and where positive results must be secured under varying conditions, without the fear of chlorinous tastes unduly influencing the choice of the dose of chlorine. De-chlorination with activated carbon still further reduces the required control of chemical dosing.

De-chlorination with ammonia permits the advantage of chloramination being utilized throughout distribution systems, or post treatment of de-chlorinated water with chlorine and ammonia provides the same benefits.

Super-chlorination also provides a means of greatly extending the

effectiveness of bacterial destruction and thus it is necessary to reappraise permissible degrees of bacterial pollution of raw waters subject to such treatment, as contrasted to conventional chlorination. It is very desirable, therefore, that comprehensive data be collected as to the effectiveness of this treatment in bacterial removal under varying conditions and with adequate factors of safety.

In summary, super-chlorination permits the use of high doses of chlorine for the following purposes without the delivered water having chlorinous tastes, and without the necessity of frequently changing the chlorine dose: (a) more certain disinfection of polluted water, especially where there is a doubt as to the required concentration of residual chlorine to secure effective results, or where the required concentration of residual chlorine produces chlorinous tastes; (b) more rapid disinfection when the reaction period is limited because of structural reasons; (c) the more adequate use of the oxidizing effect of chlorine in the destruction of protective organic colloids and in the oxidation of iron and manganese, whereby improved coagulation is secured; (d) the control of algae and other microorganisms in coagulation basins and in filter beds; (e) the prevention of chlorinous tastes where alkaline waters are treated and when stable hypochlorite compounds otherwise are produced; and (f) the destruction of taste producing compounds.

Author's Closure: Further review of the literature reveals that Gerstein (Jour. A. W. W. A., **23:** 1347 (1931)) records results of successive chlorine increments similar to those illustrated in figs. 3 and 4. A paper by R. D. Scott (Report of 8th Ohio Conf. on Water Purification, p. 60 (published, 1929)), entitled "Research on Removal of Phenolic Tastes in Public Water Supplies," contains the following:

"It was observed with both natural waters and water dosed with phenols that up to a certain point, progressive increases in chorine dosages often resulted in an actual decrease in residual chlorine. . . . It is suggested that the chlorine dosage required to produce the first progressive increase in residual chlorine might be designated as the super-chlorination value of the water. The data so far secured indicate that this value is a measure of the chlorine dosage required to eliminate chlorophenol tastes."

It is surprising that these apt comments, made by Mr. Scott in 1928, should have received no attention or recognition. Certainly both experience with the process on a plant scale and laboratory studies today demonstrate the truth of his prediction.

Typhoid in Large Cities of the United States in 1938

THE means employed for obtaining data for this report were described last year. A communication was addressed to the health officer of each of the ninety-three cities, requesting the number of deaths from typhoid both among residents and among nonresidents which were recorded for 1938. The difficulty of obtaining an adequate estimate of population continues and will harass the public health official until the 1940 census has been completed. In all instances the local estimate when furnished by the health officer has been used. There are some who feel that their cities have grown slightly during the past years and others take credit for a decrease in population. Study indicates that in no instance is a grave statistical error committed by using the local estimate rather than falling back on the 1930 census figures. It is hoped that after the 1940 figures become available these tables can be revised, but even then it is anticipated that the corrections will be of only a minor character.

Paratyphoid has again been excluded. In tables 1 to 8 inclusive (as well as in table 10) a special note has been made of cities in which all deaths occur among nonresidents. Similar notation has been added for the death rates for 1936 and 1937 but in no instance for preceding years. Another symbol has been used to indicate those cities in which more than one third of the reported deaths were stated to have been among nonresidents.

Special attention is called to the cities listed in table 9 which report no typhoid death during the past two years. Bridgeport reports no death in five years, Fort Wayne no death in four years, South Bend and Utica no death in three years. Attention is also directed to the

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seven cities (Toledo, Hartford, Syracuse, Worcester, Springfield, Evansville and Camden) which are placed among those of first rank rather than on the honor roll in table 10 merely because they have been charged with deaths among nonresidents. It is quite appropriate to think of these cities as belonging in the honor group. Local circumstances beyond the control of the public health officer frequently require the hospitalization in large cities of cases which

TABLE 1

Death Rates of Fourteen Cities in New England States from Typhoid per Hundred Thousand of Population

	1938	1937	1936	1931–1935	1926–1930	1921–1925	1916–1920	1911–1915	1906–1910
Bridgeport	0.0	0.0	0.0	0.3	0.5	2.2	4.8	5.0	10.3
Fall River	0.0	0.0	0.9	0.2°	2.2	2.3	8.5	13.4	13.5
Lynn	0.0	0.0	1.0	0.2	1.5	1.6	3.9	7.2	14.1
New Bedford	0.0	0.0	1.8	1.1°	1.5	1.7	6.0	15.0	16.1
Providence	0.0	0.4	0.8	1.1	1.3	1.8	3.8	8.7	21.5
Cambridge	0.0	0.8	0.0	0.9	2.1	4.3	2.5	4.0	9.8
Lowell	0.0	1.0	1.0	1.0°	2.6	2.4	5.2	10.2	13.9
Worcester	0.5*	0.5*	0.0	0.6	1.0	2.3	3.5	5.0	11.8
Hartford	0.5*	1.1	0.5	1.2	1.3	2.5	6.0	15.0	19.0
Boston	0.6†	0.4*	0.1*	0.6	1.2	2.2	2.5	9.0	16.0
Springfield	0.7*	0.7*	0.0	1.0	0.4	2.0	4.4	17.6	19.9
Waterbury	0.9	0.0	0.0	0.4	1.2	1.0	8.0	18.8	—
Somerville	1.0	0.0	0.0	0.4	1.3	1.6	2.8	7.9	12.1
New Haven	1.2†	1.2	1.2	0.7	0.6	4.4	6.8	18.2	30.8

* All typhoid deaths were stated to be in nonresidents.

° Rate computed from population as of April 1, 1930, as no estimate for July 1, 1933, was made by the Census Bureau.

† One third or more of the reported typhoid deaths were stated to be in nonresidents.

belong in the surrounding rural communities. This same comment applies to those cities in which a relatively high share of the typhoid deaths occurred among nonresidents.

Seven of the large New England cities report no death from typhoid in 1938 (table 1). Only four of these cities (Bridgeport, Fall River, Lynn, New Bedford) were in this same honor group in 1937. Bridgeport has extended its good record to five years. Somerville, which last year recorded no death for four years in succession, reports one death among residents in 1938. Springfield, after passing through a

period of three successive years with no death among residents, reports one death among nonresidents in 1938. Providence reports no death in 1938 among twelve resident patients. Three of these cases occurred in one family and are attributed to the fact that children were playing near an old privy. Of two deaths reported from New Haven, one occurred in a nonresident. Of five deaths reported from Boston, three were among nonresidents. Hartford, with but one death and that in a nonresident, reports that in 1936, during the Connecticut River flood, 97,334 typhoid inoculations were given and that during the 1938 flood 4,435 such protective treatments were administered to Hartford residents. The New England cities as a whole (population 2,645,438), although reporting a rate as low as that for 1937, have lost first place among the grouped cities (table 13). The lowest rate, of 0.35, is reported from the East North Central states, while second place goes to the West North Central cities and third place to the Middle Atlantic cities. In the New England cities there were recorded twelve deaths in 1938, a number identical with that of 1937.

The Middle Atlantic states have a group rate (0.44) which is significantly lower than that of 1937 (0.51). The 1938 rate is slightly below that of the New England cities and is nearly half the rate of the Middle Atlantic cities for the quinquennial period 1931-1935 (0.80). There has been no death recorded in Utica for the past three years. Syracuse continued to hold her place of honor in that there was recorded no death among residents in 1938, but the record of this city has been somewhat embarrassed by the occurrence of one typhoid death among nonresidents in 1938. Six cities in this group report no typhoid death in 1938. There were seven such cities in 1937. Utica and Reading are the only two cities reporting no death in each of these two years. Buffalo, Scranton, Erie and Syracuse record no death among residents during the past two years. Scranton, as in the case of Springfield, has passed through five consecutive years with no death among residents. Paterson, with no death in 1937, records one death among residents in 1938. Newark, with no death in 1937, reports two among residents in 1938. New York reports twenty-two deaths, of which twenty were among residents. Pittsburgh reports six deaths, three among residents. Philadelphia reports fifteen deaths, all among residents. In the group as a whole (population 13,469,996) there were fifty-nine deaths in 1938 compared with sixty-eight in the preceding year. There are two geographic areas

which have a lower death rate for 1938, the East North Central and the West North Central.

The rate for the South Atlantic cities (1.74) is much improved over that of 1937 (1.96) but is not as low as that of 1936 (1.55). In

TABLE 2

Death Rates of Eighteen Cities in Middle Atlantic States from Typhoid per Hundred Thousand of Population

	1938	1937	1936	1931–1935	1926–1930	1921–1925	1916–1920	1911–1915	1906–1910
Utica	0.0	0.0	0.0	0.6	1.1	3.9✱	—	—	—
Reading	0.0	0.0	1.8	0.4	1.6	6.0	10.0	31.9	42.0
Buffalo	0.0	0.2*	0.3	0.6	2.7	3.9	8.1	15.4	22.8
Scranton	0.0¶	0.7*¶	0.0¶‡	1.4	1.8	2.4	3.8	9.3	31.5
Erie	0.0	0.8*	0.8*	1.0	0.9	2.3	6.9	49.0	46.6
Elizabeth	0.0	0.8	0.8	0.9	1.6	2.4	3.3	8.0	16.6
Rochester	0.3	0.0	0.6†	0.4	1.7	2.1	2.9	9.6	12.8
New York	0.3	0.3	0.4	0.8	1.3	2.6	3.2	8.0	13.5
Newark	0.4	0.0	0.2	0.3	0.9	2.3	3.3	6.8	14.6
Syracuse	0.5*	0.0	0.0	0.8	0.8	2.3	7.7	12.3	15.6
Paterson	0.7	0.0	0.7	0.9	1.0	3.3	4.1	9.1	19.3
Yonkers	0.7	0.0	0.7‖	0.7	0.5	1.7	4.8	5.0	10.3
Philadelphia	0.7¶	1.4	0.7	0.9	1.1	2.2	4.9	11.2	41.7
Jersey City	0.9	0.3	0.6*	0.2	0.9	2.7	4.5	7.2	12.6
Pittsburgh	0.9†	0.7†	0.7†	0.9	2.4	3.9	7.7	15.9	65.0
Albany	1.4	1.3†	1.5	1.1	1.8	5.6	8.0	18.6	17.4
Camden	1.6*	1.6	0.8	2.8	4.4	5.9	4.9	4.5	4.0
Trenton	2.4†	0.8*	0.8*	1.1	2.1	8.2	8.6	22.3	28.1

* All typhoid deaths were stated to be in nonresidents.

† One third or more of the reported typhoid deaths were stated to be in nonresidents.

✱ Incomplete data.

¶ Typhoid deaths furnished by Pennsylvania Department of Health, Harrisburg.

‡ Rate computed from 1930 census population, as no local estimate was given.

‖ Corrected rate. In review for 1936, Yonkers reported cases instead of deaths.

these cities (population 2,638,626) there occurred forty-six deaths in 1938 and fifty-one in 1937. There was no city without a death in 1938, although six of the nine cities in this group report that one third or more of the deaths occurred among nonresidents. Baltimore reports thirteen deaths, eight among residents. It is reported that,

in investigating sources of infection in typhoid cases, there were located sixteen carriers presumably responsible for twenty cases. Many cities in the South continue to be embarrassed by the high percentage of deaths among nonresidents. The large cities serve as hospital centers for the neighboring suburban and rural areas which are without adequate means of caring for the communicable diseases and which frequently suffer from the want of whole-time local public health supervision. Of five deaths recorded for Richmond, four were among nonresidents; of six in Washington, two were among nonresidents. Three deaths among nonresidents are included among the five deaths reported for Miami. It is stated that for one nonresident

TABLE 3

Death Rates of Nine Cities in South Atlantic States from Typhoid per Hundred Thousand of Population

	1938	1937	1936	1931–1935	1926–1930	1921–1925	1916–1920	1911–1915	1906–1910
Norfolk	0.8	0.8	0.0	4.2	2.2	2.8	8.8	21.7	42.1
Atlanta	0.9†	1.9†	3.2†	7.2	11.1	14.5	14.2	31.4	58.4
Washington	1.0†	1.9	1.6	2.6	2.8	5.4	9.5	17.2	36.7
Baltimore	1.5†	1.2	0.9	1.4	3.2	4.0	11.8	23.7	35.1
Tampa	2.0†	0.0	0.0	3.0	3.8	19.1	43.9*	—	—
Wilmington	2.7	1.8	0.9	1.5	3.1	4.7	25.8*	23.2*	33.0
Richmond	2.7†	3.2†	2.7	2.5	1.9	5.7	9.7	15.7	34.0
Miami	3.6†	6.3	3.1†	2.2	3.5	—	—	—	—
Jacksonville	5.2	4.0	1.3	1.7	4.4	—	—	—	—

* Incomplete data.

† One third or more of the reported typhoid deaths were stated to be in nonresidents.

death the infection was contracted prior to the arrival of the patient in Florida. Miami originally reported eight deaths for the year 1937. The director of health states that this should now be changed to six deaths for that year. Of eight deaths recorded by Jacksonville, but one occurred in a nonresident. The health department reports that a plan is being developed to require inoculation of all food handlers against tyhpoid. This city continues to serve as a medical center for seven or eight nearby rural counties with no public health units. Such a unit has, however, recently been established in Duval County, which includes the territory immediately surrounding Jacksonville. After two consecutive years with no typhoid death, Tampa records one death among residents for two reported in 1938.

The East North Central cities (population 9,907,440) can boast of the best record for 1938 (rate 0.35). In 1937 there were sixty-one deaths reported from these cities. In 1938 the number of deaths had dropped to thirty-five. There are seven cities which report no death and two additional cities (Toledo, Evansville) which record

TABLE 4

Death Rates of Eighteen Cities in East North Central States from Typhoid per Hundred Thousand of Population

	1938	1937	1936	1931–1935	1926–1930	1921–1925	1916–1920	1911–1915	1906–1910
Fort Wayne	0.0	0.0	0.0	2.2	4.2	12.9	7.3	—	—
South Bend	0.0	0.0	0.0	0.7	—	—	—	—	—
Milwaukee	0.0	0.0	0.3	0.2	0.8	1.6	6.5	13.6	27.0
Canton	0.0	0.0	1.0°	0.9	1.4	3.3	8.9	—	—
Grand Rapids	0.0	1.0*	0.6*	0.2	1.0	1.9	9.1	25.5	29.7
Youngstown	0.0	1.1	1.1†	1.1	1.1	7.2	19.2	29.5	35.1
Peoria	0.0	1.7*	1.7*	0.9	0.2	3.7	5.7	16.4	15.7⁂
Detroit	0.2†	0.3	0.5	0.6	1.3	4.1	8.1	15.4	22.8
Chicago	0.3	0.3	0.3	0.4	0.6	1.4	2.4	8.2	15.8
Cleveland	0.3†	0.5	1.0	1.1	1.0	2.0	4.0	10.0	15.7
Toledo	0.3*	1.2*	1.0†	1.3	3.0	5.8	10.6	31.4	37.5
Columbus	0.3	1.5	3.7*	2.0	2.1	3.5	7.1	15.8	40.0
Akron	0.4	1.6†	0.8†	0.8	1.5	2.4	10.6	21.0	27.7⁂
Cincinnati	0.6	1.3†	1.9†	1.4	2.5	3.2	3.4	7.8	30.1
Evansville	0.9*	2.7†	0.0	1.9	6.2	5.0	17.5	32.0	35.0
Flint	1.2	3.0†	1.2	0.7	1.6	4.6	22.7	18.8	46.9
Indianapolis	1.3	1.3	0.8†	1.2	2.7	4.6	10.3	20.5	30.4
Dayton	1.3†	1.4†	1.8†	0.8	1.9	3.3	9.3	14.8	22.5

* All typhoid deaths were stated to be in nonresidents.

† One third or more of the reported typhoid deaths were stated to be in nonresidents.

⁂ Incomplete data.

° Rate computed from 1930 census population, as no local estimate was given.

no death among residents. In addition to this there are three cities (Detroit, Cleveland, Dayton) in which one third or more of the reported cases were stated to be in nonresidents. Fort Wayne reports no typhoid death in four years, South Bend no death in three years, Milwaukee and Canton no death in two years. There has been no death among residents in Grand Rapids and Peoria during the past four years. Toledo reports no resident death in two years. Dayton

records a significantly high proportion of deaths among nonresidents during each of the past three years. Of three deaths each in Cleveland and Detroit, one in each city was of a nonresident. Chicago reports a total of twelve deaths, two of which were stated to be in nonresidents.

The six cities in the East South Central Group show an increase in the death rate (2.10 in 1937, 2.36 in 1938). This rate, however, is considerably below that of 1936 (3.35) and that of the quinquennial period 1931–1935 (4.81). The actual number of deaths in these six cities increased from twenty-eight in 1937 to thirty-two in 1938.

TABLE 5

Death Rates of Six Cities in East South Central States from Typhoid per Hundred Thousand of Population

	1938	1937	1936	1931–1935	1926–1930	1921–1925	1916–1920	1911–1915	1906–1910
Louisville	0.8†	0.6*	1.4†	2.3	3.7	4.9	9.7	19.7	52.7
Birmingham	1.7†	1.4	5.0°	3.9	8.0	10.8	31.5	41.3	41.7
Chattanooga	1.7	1.7	0.0	4.7	8.0	18.6	27.2	35.8⁂	—
Memphis	3.1†	4.9†	4.7†	7.9	9.3	18.9	27.7	42.5	35.3
Knoxville	3.9	3.2	4.1	5.7	10.7	20.8	25.3⁂	—	—
Nashville	4.9†	1.2*	4.4†	5.6	18.2	17.8	20.7	40.2	61.2

* All typhoid deaths were stated to be in nonresidents.

† One third or more of the reported typhoid deaths were stated to be in nonresidents.

⁂ Incomplete data.

° Rate computed from 1930 census population, as no local estimate was given.

No city in this group is without a death in 1938. The influence of the surrounding rural areas in contributing to the hospital load and thus to the death rate of the urban centers in the South is well illustrated by the fact that in Birmingham, Memphis and Nashville more than one third of the deaths were among nonresidents. Birmingham, with five deaths, reports two in nonresidents; Memphis, with nine deaths, records four in nonresidents; Nashville, with eight deaths, reports three in nonresidents. Chattanooga reports two deaths among residents, with a comment that in both instances the source of infection was outside the city. Special mention of the influence of the surrounding rural area and the Negro population on the death rate for Memphis was made in our report a year ago.

The West North Central group (population 2,785,688) reports a noteworthy reduction in the death rate (0.76 in 1937, 0.40 in 1938). There is but one group of cities (East North Central) which has a lower death rate. Four cities (Wichita, Minneapolis, Kansas City, Kan., Omaha) report no typhoid death in 1938 and the first three of these record no death among residents in 1937. Minneapolis has had no death in a resident during the past three years. Duluth, after two years with no death, now reports a single death in a resident. This death, however, is sufficient to move Duluth from the head to the bottom of the table. This is the only group in which there is no

TABLE 6

Death Rates of Nine Cities in West North Central States from Typhoid per Hundred Thousand of Population

	1938	1937	1936	1931-1935	1926-1930	1921-1925	1916-1920	1911-1915	1906-1910
Wichita	0.0	0.0	1.9	0.7	1.2	6.3	—	—	—
Minneapolis	0.0	0.2*	0.0	0.8	0.8	1.9	5.0	10.6	32.1
Kansas City, Kan.	0.0	0.8*	2.3	1.1	1.7	5.0	9.4	31.1	74.5#
Omaha	0.0	1.3	0.9*	0.9	1.3	3.3	5.7	14.9	40.7
St. Louis	0.5	1.1†	0.8	1.6	2.1	3.9	6.5	12.1	14.7
St. Paul	0.7	0.0	0.7	0.7	1.4	3.4	3.1	9.2	12.8
Des Moines	0.7	0.7	2.8	2.1	2.4	2.2	6.4	15.9	23.7
Kansas City, Mo.	0.7†	1.4†	0.5	1.5	2.8	5.7	10.6	16.2	35.6
Duluth	1.0	0.0	0.0	1.0	1.1	1.7	4.4	19.8	45.5

* All typhoid deaths were stated to be in nonresidents.

† One third or more of the reported typhoid deaths were stated to be in nonresidents.

Incomplete data.

city with a death rate in excess of 1.0. Not only do these cities as a group have a low death rate but actually the lowest number of deaths. There were eleven deaths in 1938, compared with twenty-one in 1937. The Iowa State Health Department reports that no statistical correction is as yet available regarding deaths among nonresidents and consequently such information is not included in the report for Des Moines. It is likely, however, that this same error might creep into the statistics of many other cities widely scattered throughout the United States.

The eight cities of the West South Central group did not fare so well. Here the rate increased from 2.34 in 1937 to 3.52 in 1938.

The actual number of deaths increased from forty-nine to seventy-four. The death rate increased in six of the eight cities, Oklahoma City and San Antonio being the only two with a lower death rate. El Paso, with no death in 1937, reports a rate of 5.9 (six deaths) in 1938. All but one of these deaths are among residents. Oklahoma City records no data concerning deaths among nonresidents. Of six deaths in San Antonio, four were among residents; of eleven in Houston, nine were among residents; of twenty-nine in New Orleans, fourteen were among residents. With no death in a resident in 1936

TABLE 7

Death Rates of Eight Cities in West South Central States from Typhoid per Hundred Thousand of Population

	1938	1937	1936	1931–1935	1926–1930	1921–1925	1916–1920	1911–1915	1906–1910
Tulsa	0.6	0.0	0.7‡	1.1	8.3	16.2✱	—	—	—
Oklahoma City	1.3	3.1	4.3‡	4.3	7.4✱	—	—	—	—
San Antonio	2.3†	3.8	2.7	4.2	4.6	9.3	23.3	29.5	35.9
Fort Worth	2.7†	2.2	3.3	4.6	5.9	6.1	16.3✱	11.9	27.8
Houston	3.1	2.0	3.8	3.2	4.8	7.6	14.2	38.1	49.5✱
Dallas	4.3†	3.0*	1.5*‡	5.4	7.3	11.2	17.2		—
New Orleans	5.5†	2.3†	6.5†	9.6	9.9	11.6	17.5	20.9	35.6
El Paso	5.9	0.0	6.8‡	4.9	9.1	10.8	30.7	42.8	—

* All typhoid deaths were stated to be in nonresidents.

† One third or more of the reported typhoid deaths were stated to be in nonresidents.

✱ Incomplete data.

‡ Rate computed from 1930 census population, as no local estimate was given.

and 1937, Dallas reports thirteen deaths for 1938, of which nine were among nonresidents.

The cities in the Mountain and Pacific states show a continued reduction in the rate (0.52 in 1938, 0.68 in 1937). There were recorded twenty-two deaths in 1938, twenty-eight deaths in 1937. In 1938 there were five cities with no death (Seattle, Tacoma, Portland, Salt Lake City, San Diego). Three additional cities (Oakland, Los Angeles, Spokane) record one third or more deaths which were in nonresidents. There was but one city with a rate in excess of 2.0 (Spokane). There were but three deaths in Spokane, two of which were among nonresidents. Two cities (Seattle, Tacoma) report no

typhoid death in 1937 and 1938. Of five deaths in San Francisco, four were among residents. Of eight deaths in Los Angeles, five were among residents. Denver does not keep a record of deaths among nonresidents.

TABLE 8

Death Rates of Eleven Cities in Mountain and Pacific States from Typhoid per Hundred Thousand of Population

	1938	1937	1936	1931–1935	1926–1930	1921–1925	1916–1920	1911–1915	1906–1910
Seattle	0.0	0.0	0.5	0.6	2.2	2.6	2.9	5.7	25.2
Tacoma	0.0	0.0	0.9	0.7	1.8	3.7	2.9	10.4	19.0
Portland	0.0	0.3	0.6	0.8	2.3	3.5	4.5	10.8	23.2
Salt Lake City	0.0	0.7	0.0	1.0	1.9	6.0	9.3	13.2	41.1
San Diego	0.0	1.6†	1.8†	1.3	1.0	1.6	7.9	17.0	10.8
Long Beach	0.6	0.0	0.6*	0.2	1.1	2.1§	—	—	—
Oakland	0.6†	0.3	0.3	1.0	1.2	2.0	3.8	8.7	21.5
Los Angeles	0.6†	0.7†	1.0†	0.8	1.5	3.0	3.6	10.7	19.0
San Francisco	0.7	0.6	0.3†	0.8	2.0	2.8	4.6	13.6	26.3
Denver	1.0	2.7	2.0	1.8	2.6	5.1	5.8	12.0	37.5
Spokane	2.4†	0.0	0.8	1.4	2.2	4.4	4.9	17.1	50.3

* All typhoid deaths were stated to be in nonresidents.

† One third or more of the reported typhoid deaths were stated to be in nonresidents.

§ Incomplete data.

TABLE 9

Thirteen Cities with No Typhoid Death in 1937 and 1938

Bridgeport*	Lynn	South Bend†
Canton	Milwaukee	Tacoma
Fall River	New Bedford	Utica†
Fort Wayne**	Reading	Wichita
	Seattle	

* No typhoid death in five years.

** No typhoid death in four years.

† No typhoid death in three years.

The number of cities with no death from typhoid has increased to twenty-nine. In 1936 there were but eighteen such cities, in 1937 twenty-seven. Of particular significance are the data in table 9, which furnishes the names of thirteen cities with no typhoid death in 1937 and 1938. Bridgeport and Fort Wayne have continued their

TABLE 10

Death Rates from Typhoid in 1938

Honor Roll: No Typhoid Deaths (Twenty-Nine Cities)

Bridgeport	Lowell	Salt Lake City
Buffalo	Lynn	San Diego
Cambridge	Milwaukee	Scranton
Canton	Minneapolis	Seattle
Elizabeth	New Bedford	South Bend
Erie	Omaha	Tacoma
Fall River	Peoria	Utica
Fort Wayne	Portland	Wichita
Grand Rapids	Providence	Youngstown
Kansas City, Kan.	Reading	

First Rank: from 0.1 to 1.9 Deaths per Hundred Thousand (Forty-Eight Cities)

Detroit	0.2†	Los Angeles	0.6†	Pittsburgh	0.9†
Chicago	0.3	Oakland	0.6†	Waterbury	0.9
Cleveland	0.3†	Tulsa	0.6	Denver	1.0
Columbus	0.3	Des Moines	0.7	Duluth	1.0
New York	0.3	Kansas City, Mo	0.7†	Somerville	1.0
Rochester	0.3	Paterson	0.7	Washington	1.0†
Toledo	0.3*	Philadelphia	0.7	Flint	1.2
Akron	0.4	San Francisco	0.7	New Haven	1.2†
Newark	0.4	Springfield	0.7*	Dayton	1.3†
Hartford	0.5*	St. Paul	0.7	Indianapolis	1.3
St. Louis	0.5	Yonkers	0.7	Oklahoma City	1.3
Syracuse	0.5*	Louisville	0.8†	Albany	1 4
Worcester	0.5*	Norfolk	0.8	Baltimore	1.5†
Boston	0.6†	Atlanta	0.9†	Camden	1.6*
Cincinnati	0.6	Evansville	0.9*	Birmingham	1.7†
Long Beach	0.6	Jersey City	0.9	Chattanooga	1.7

Second Rank: from 2.0 to 4.9 (Thirteen Cities)

Tampa	2.0†	Richmond	2.7†	Knoxville	3.9
San Antonio	2.3	Wilmington	2.7	Dallas	4.3†
Spokane	2.4†	Houston	3.1	Nashville	4.9†
Trenton	2.4†	Memphis	3.1†		
Fort Worth	2.7†	Miami	3.6†		

Third Rank: from 5.0 to 5.9 (Three Cities)

Jacksonville	5.2
New Orleans	5.5†
El Paso	5.9

* All typhoid deaths were stated to be in nonresidents.

† One third or more of the reported typhoid deaths were stated to be in nonresidents.

excellent records. While last year there was but one city in the third rank (Miami), and this city would not have been included in this rank had the correct number of deaths been recorded, in 1938 we find three cities in this group, only one of which reports a significant number of deaths among nonresidents. As already stated, several of the cities in the first rank would appear in the honor roll were they not charged with deaths in nonresidents. Table 11 continues to show a swing "to the right," although the number of cities in the group having death rates from 5.0 to 9.9 has increased from one to three.

TABLE 11

Number of Cities with Various Typhoid Death Rates

	NO. OF CITIES	10.0 AND OVER	5.0 TO 9.9	2.0 TO 4.9	1.0 TO 1.9	0.1 TO 0.9	0.0
1906–1910	77	75	2	0	0	0	0
1911–1915	79	58	19	2	0	0	0
1916–1920	84	22	32	30	0	0	0
1921–1925	89	12	17	48	12	0	0
1926–1930	92	3	10	30	37	12	0
1931–1935	93	0	6	17	28	42	0
1930	93	2	6	30	23	22	10
1931	93	2	6	23	28	22	12
1932	93	1	7	13	29	29	14
1933	93	0	7	18	19	33	16
1934	93	0	9	11	27	23	23
1935	93	0	7	15	18	29	24
1936	93	0	3	15	21	36	18
1937	93	0	1	13	26	26	27
1938	93	0	3	13	14	34	29

For the seventy-eight cities (table 12) for which complete data are available since 1910, there occurred 248 deaths from typhoid in 1938, which is the lowest of record (280 in 1937, 336 in 1936). The rate for this group of cities is for the fourth consecutive year less than 1.0. The rate for the ninety-three cities studied in 1938 is also below 1.0 (0.74) and below the corresponding rate for 1937 (0.82). This annual review again showed a downward trend in the death rate from typhoid in the large cities of the United States. No outbreak of epidemic proportion has been recorded in these cities. Routine vaccination of the population is not practiced except under flood conditions. How-

TABLE 12

*Total Typhoid Rate for Seventy-Eight Cities 1910–1938**

	POPULATION	TYPHOID DEATHS	TYPHOID DEATH RATE PER 100,000
1910	22,573,435	4,637	20.54
1911	23,211,341	3,950	17.02
1912	23,835,399	3,132	13.14
1913	24,457,989	3,285	13.43
1914	25,091,112	2,781	11.08
1915	25,713,346	2,434	9.47
1916	26,257,550	2,191	8.34
1917	26,865,408	2,016	7.50
1918	27,086,696†	1,824†	6.73
1919	27,735,083†	1,151†	4.15
1920	28,244,878	1,088	3.85
1921	28,859,062	1,141	3.95
1922	29,473,246	963	3.26
1923	30,087,430	950	3.16
1924	30,701,614	943	3.07
1925	31,315,598	1,079	3.44
1926	31,929,782	907	2.84
1927	32,543,966	648	1.99
1928	33,158,150	628	1.89
1929	33,772,334	537	1.59
1930	34,386,717	554	1.61
1931	35,137,915	563	1.60
1932	35,691,815	442	1.24
1933	35,691,815	423	1.18
1934	35,401,715	413	1.17
1935	35,401,715	348	0.98‡
1936	36,216,404	336	0.93§
1937	36,771,787	280	0.76 ⁂
1938	36,972,985	248	0.67 ⁂ ⁂

* The following fifteen cities are omitted from this table because data for the full period are not available: Canton, Chattanooga, Dallas, Fort Wayne, Jacksonville, Knoxville, Long Beach, Miami, Oklahoma City, South Bend, Tampa, Tulsa, Utica, Wichita, Wilmington.

† Data for Forth Worth lacking.

‡ The rate for ninety-three cities in 1935 was 1.03 (total population 37,437,812, typhoid deaths 385), whereas in 1930 it was 1.64, and in 1933 and 1934 it was 1.24 and 1.25, respectively. The 1931–1935 average for the ninety-three cities is 1.31.

§ Rate for ninety-three cities in 1936 was 0.96 (total population 38,249,094, typhoid deaths 365).

⁂ Rate for ninety-three cities in 1937 was 0.82 (total population 38,885,435, typhoid deaths 318).

⁂ ⁂ Rate for ninety-three cities in 1938 was 0.74 (total population 39,143,556, typhoid deaths 291).

Special Note.—Deaths for 1936 have been corrected, as Yonkers originally reported seven deaths and later corrected report to one death.

ever, in progressive communities vaccination is urged for contacts to cases and for persons who travel widely in countries where sanitary conditions are not of the best. There seems to be a trend in some places to encourage the inoculation of foodhandlers, especially in the

TABLE 13

Total Typhoid Death Rate per Hundred Thousand of Population for Ninety-Three Cities According to Geographic Division

	POPULATION	TYPHOID DEATHS		TYPHOID DEATH RATES				
		1938	1937	1938	1937	1931–1935	1926–1930	1925
New England	2,645,438	12	12	0.45	0.45	0.70	1.31	2.48
Middle Atlantic	13,469,996	59	68	0.44	0.51	0.80	1.40	2.97
South Atlantic	2,638,626	46	51	1.74	1.96	2.70	4.50	7.01*
East North Central	9,907,440	35	61	0.35	0.62	0.75	1.29†	2.32†
East South Central	1,355,080	32	28	2.36	2.10	4.81	8.31	13.00
West North Central	2,785,688	11	21	0.40	0.76	1.24	1.83	3.43
West South Central	2,120,553	74	49	3.52	2.34	5.36	7.32‡	13.08§
Mountain and Pacific	4,220,735	22	28	0.52	0.68	0.88	1.80	2.33

* Lacks data for Jacksonville and Miami.

† Data for South Bend for 1925–1929 are not available.

‡ Lacks data for Oklahoma City in 1926.

§ Lacks data for Oklahoma City.

Southern states. The noteworthy gains for 1938 have been made in the East North Central and West North Central cities. The New England and Middle Atlantic groups have, on the whole, maintained their excellent rates of many years' standing.

Tacoma's Water Works Construction Program

By W. A. Kunigk

THE Water Department of the city of Tacoma has, during the last four to five years, taken full advantage of federal government aid offered to municipally owned utilities in carrying out a work relief program of necessary improvements and expansion in the supply and distribution system facilities. On account of the curtailed income during the corresponding period, particularly from commercial service, it would have been impossible to carry out this necessary work without federal help.

While some of the funds for these improvements came from the income of the Water Department, the greater portion thereof was provided through the sale of revenue bonds and through federal grants and contributions.

In order that all improvements in the water system might be carried out in an orderly manner and to the greatest possible benefit to the city of Tacoma as a whole, a long range program of reconstruction, expansion and betterments was planned a number of years ago. This program has been followed in general in carrying out all improvements and particularly those enumerated in this paper.

In setting up this general long range program due consideration has been given to the following points:

(1) The replacement of those units in the system which have outlived their usefulness on account of physical depreciation or functional obsolescence.

(2) Provision has been made in the replacement for the normal increase in demand by increasing capacities of the supply and distribution systems.

A paper presented on May 12, 1939, at the Pacific Northwest Section Meeting at Tacoma, Washington, by W. A. Kunigk, Superintendent, Water Division, Tacoma.

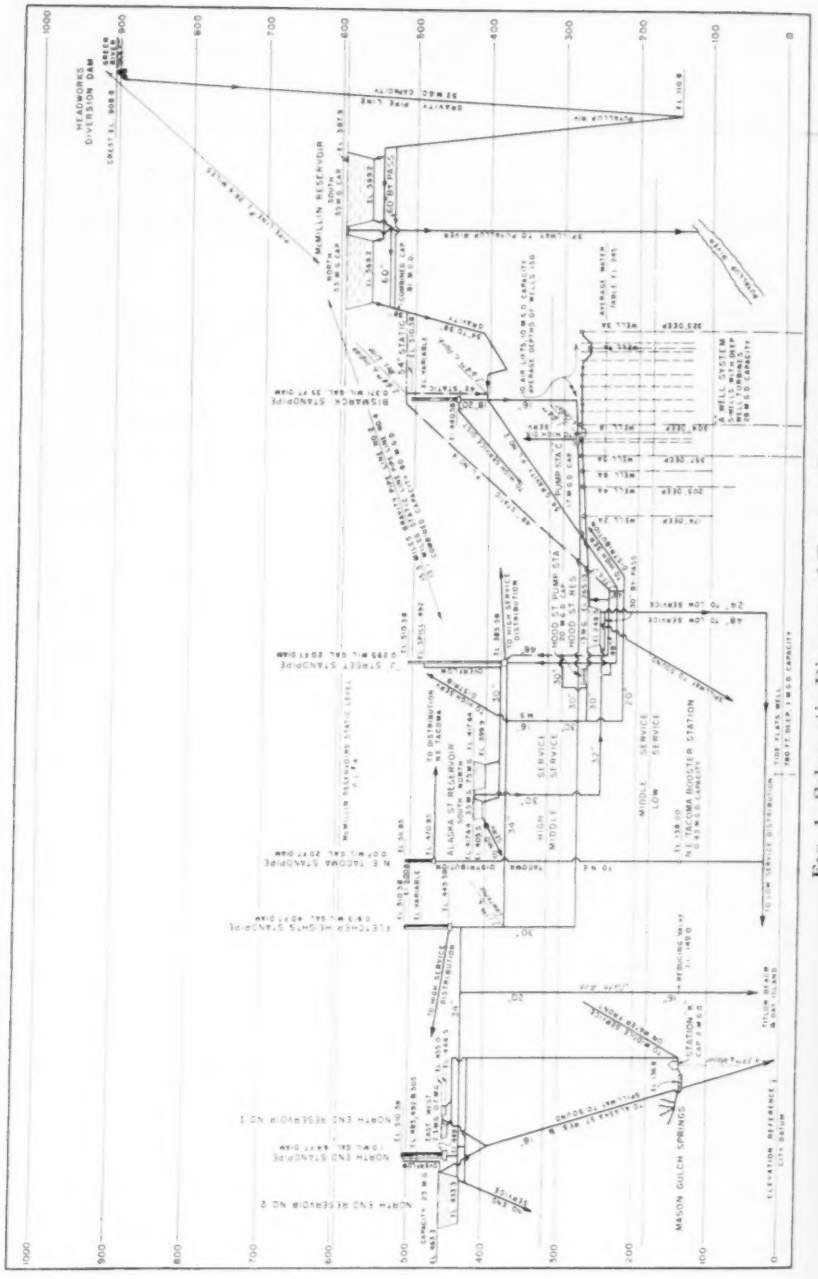

FIG. 1. Schematic Diagram of Tacoma System

(3) Detailed study has been given to the coordination of the construction program expenditures with those necessary for operation, maintenance, interest and redemption of present and proposed bond obligations and depreciation within the estimated earnings of the department during the corresponding period.

This general long range plan is not a hard and fast program that the department follows rigidly, but is used as a general guide, subject to revision from year to year in line with current development and requirements. So, when the federal government in 1933 decided to provide relief work in order to alleviate the suffering of many thousands of citizens then unemployed and offered to finance among other things worthwhile construction work of municipally owned utilities,

TABLE 1

Summary of Sources of Funds and Costs of Improvements

SOURCE	CITY'S COST	FEDERAL COST	TOTAL COST
P. W. A.	$2,312,700.71	$1,377,377.53	$3,690,078.24
W. P. A.	73,678.40	228,086.16	301,764.56
C. W. A.	24,498.63	6,552.75	31,051.38
C. C. C.		224,000.00	224,000.00
U. S. G. S.	6,000.00	6,000.00	12,000.00
Water Fund	398,455.73		398,455.73
Totals	$2,815,333.47	$1,842,016.44	$4,657,349.91

it was but a comparatively simple matter for the Water Department to prepare plans and specifications with the minimum loss of time for a program of construction that is sound and will fit into the general scheme of the long range plan already mentioned.

A great variety of improvements is covered by this program and these are described in some detail below. Table 1 is a summary which shows the sources of funds for the program. For the convenience of the reader, a schematic diagram of the gravity, wells and distribution system is given as fig. 1.

One of the first projects was the construction of many miles of patrol roads, trails and telephone lines in the Green River Watershed by the C. C. C. organization which was housed in a camp near Lester on the Green River Watershed. Fire guards were cut and several lookout towers were built, facilitating to a large extent the patrol

FIG. 1. Schematic Diagram of Tacoma System

FIG. 2. Green River Gravity Pipe Line System

work of the forest rangers during the fire danger season. Inasmuch as the Green River Watershed covers about 231 square miles of mountainous and wooded country in the Cascade range with about two-thirds of the total area within the Snoqualmie National Forest Reserve, this work was carried out under the direction of the Forestry Department. The camp itself was under the direction of army officers and was at all times kept in excellent sanitary condition. No sanitary trouble was, therefore, experienced on account of the presence of some 220 men in the watershed area for a period of about sixteen months. The work done by this organization will be of permanent value in perpetuating Tacoma's principal source of water supply.

There were three P. W. A. projects in connection with the reconstruction and extension of 20.38 miles of the Green River Gravity Pipe Line system, varying in diameter from 42 in. to 63 in. (see fig. 2). Electrically welded steel pipe, coated with paint or coal tar enamel and wrapped with asbestos felt on the outside, was used for a portion of this installation (fig. 3). For the balance, centrifugally spun reinforced concrete pipe was used for those units operating under heads less than 120 ft., and for heads above 120 ft. and up to 300 ft., steel cylinder reinforced concrete lock joint pipe was installed (figs. 4 and 5).

The first C. W. A. project for the department provided for bank protection on the Green River near Palmer Junction where erosion from a changing river channel during the flood of 1933 nearly wrecked the 60 in. diameter gravity supply line. The water department had one other C. W. A. project which cleared and provided proper drainage for the 42-acre reservoir site near McMillin where the present 110 million gallon capacity gravity system reservoir is located.

The McMillin Reservoir site was beautified through two W. P. A. projects. This work included grading, construction of sidewalks, guard rails, sprinkling systems, rock work, seeding of lawn areas and planting of shrubs and trees. Two other W. P. A. projects had to do with beautifying the Alaska and North End Reservoir sites and the Mason Gulch property owned by the water department, all located inside the city limits. The work on these projects was similar to that carried out at the McMillin Reservoir site. In all of the beautifying work carried out by the department native trees and shrubs have been used, the commonest being rhododendrons, firs, hemlock, jack pine, kinnikinic, etc. A tree that has been found particularly

adaptable and decorative for this work is the Port Orford Cedar. This tree is very hardy, grows almost any place, can be readily transplanted and may be trimmed to any shape desired. In all beautifying work, particularly around the reservoirs, it has been the aim of the department to provide bank protection against erosion and parked areas of lawns and shrubs that may be maintained at a minimum of expense.

One of the so-called "white collar" W. P. A. Projects provided for a complete check and re-survey of the entire distribution system

FIG. 3. 63-inch Electric Welded Steel Pipe Installation on the Gravity System near Palmer. Note suspended pipe construction to right of center concrete anchor pier supported on rockers and pipe to left entering ground.

against the available records. The field work on this project was carried out by four 4-man crews, each consisting of a recorder, two chainmen and one laborer with a pick and shovel. One crew was especially trained to handle leak and pipe locating instruments. The mapping in the office was taken care of by two to three draftsmen. This project was under the general direction of one office engineer who devoted about one-fourth of his time to keeping this work organized. In the field the work was supervised by one full-time field engineer, working under the general direction of the office engineer. Many corrections and additions were made in the records and 178

additional counter maps were added to the office records of the distribution system.

A W. P. A. project provided for beautifying grounds in the vicinity of the Green River Headworks and the Purification Plant. Some

FIG. 4

FIG. 5

FIG. 4. 63-inch Centrifugally Spun Concrete Pipe Installation on the Gravity System near Palmer. Field joints made with grout of 1 part cement to 1½ parts sand.

FIG. 5. 58-inch Steel Cylinder Concrete Lock Joint Pipe on Green River Gravity System between McMillin Reservoir and the City. First pipe of this type made in 16-foot lengths. This type of pipe used on the Gravity System for heads up to 300 ft.

river protection work and a 4 ft. x 7 ft. concrete lined tunnel, 210 ft. long, were also included in this improvement. Another W. P. A. Project called for the clearing and burning of heavy underbrush and of all down timber on the 160 acre tract of the Maplewood Springs property. This property is held by the department for a possible future well development.

The United States Geological Survey and the City Water Department are cooperating on an investigation to determine the possible ultimate development of underground water resources in the vicinity of Tacoma. Arthur M. Piper of the Portland office of the U. S. G. S. is in charge of this project for the federal government. This work has been under way for over a year and a half and will be completed during 1939.

Another W. P. A. project called for a pile and brush bulkhead, 1,500 feet long and also included some 10,000 cubic yards of heavy riprap work for bank protection at the pipe line crossing over the Puyallup River near McMillin. This work was jointly sponsored by the City Water Department and Pierce County.

Two W. P. A. projects have been for the laying of mains. Under one project 1,170 ft. of 12-inch cast-iron pipe were laid in South 35th Street to provide a sufficient water supply for the department's new store and shop building which was completed during last winter.

Another project called for the installation of 1,920 ft. of 4-inch and 2,280 ft. of 6-inch transite pipe to provide a much needed water supply for a district along the city limits on South 96th Street. A W. P. A. Project most lately under way provides for the paving, installation of a sprinkler system and the beautifying of parking areas around the department's new store and shop building on South 35th Street and Union Avenue.

The fourth P. W. A. Project of the Water Department is now in progress. This project covers the installation of approximately 5 miles of 58-inch steel cylinder lock joint concrete pipe replacing a 54 in. diameter section of the old wooden pipe line on the gravity system (fig. 1) and the installation of 1.2 miles of electric welded steel pipe of 24 to 42 in. in diameter crossing the Puyallup River over the South 21st Street Bridge and extending along Lincoln and Sitcum Avenues over to East 11th Street. This steel main extension serves primarily the purpose of increasing the capacity of the tide flats trunk main system. There are also included in this project the installation of 14.3 miles of cast-iron and steel trunk distribution mains 12 to 30 in. in diameter in various parts of the city with 27 additional 6-inch hydrants located in the high value district of the business section of the city. There are further included in the project two or more deep wells with a required delivery capacity of not less than 12 million gallons daily and a booster pumping plant to be located at South 62nd and Cedar Streets for the purpose of boosting well water into the

high service section of the city's distribution system. This booster pumping station is designed for a capacity of 20 million gallons daily.

The city has recently completed a modern concrete store and shop building which is 160 ft. by 245.7 ft. All shop work, such as testing meters, pipe fitting, reconditioning of reclaimed materials, etc., is done in the various shops provided in this building. The operation and maintenance work in the distribution system is directed from here. This building is equipped with all the modern appliances for convenient handling of heavy equipment or fittings, gates or pipe, etc., which is of great advantage, particularly in emergency work. There are two 3-ton bridge cranes and a monorail system of equal capacity, serving every part of the building necessary. There are also provided offices for the storekeepers, foremen and inspectors as well as washing and drying rooms and lockers for the crews. A fire-proof vault has also been provided in this building where it is proposed to store all duplicate City Hall records. Car storage space and a car service and gas station in this building are of particular help in servicing cars at night, thereby cutting down lost time and increasing the efficiency of the various crews. Laboratory space has been set aside in one part of the building for the convenience of testing materials used by the department, such as paint, cement, pipe, etc.

Another job done by the city was the extension of the low service tide flats main from East 27th and "D" Streets to the 21st Street Puyallup River Bridge. This pipe line consists of 1.79 miles electrically welded steel pipe 30 to 48 in. in diameter, coated with coal tar enamel and protected with a double wrap of asbestos felt.

Summary of Benefits

The practical benefits gained from this construction program may be summed up briefly as follows:

The construction of 25.3 miles of permanent pipe line construction will eliminate many hazards in operation and will eliminate the maintenance expense of the wood stave pipe line of the original Green River Gravity System which has been replaced. By using larger diameter pipe in all cases of replacement and providing practically a duplicate pipe line from McMillin Reservoir to the city, the capacity of the gravity system from the headworks to McMillin Reservoir has been increased from 42 to 52 m.g.d. and the capacity of the duplicate lines from McMillin Reservoir to the city has been increased to 80

m.g.d. By doing so, daily peak loads of almost twice the capacity of the original system can be taken care of by the present water system without resorting to pumping water from the well supply into the distribution system.

The duplicate pipe lines from McMillin Reservoir to the city will also greatly facilitate the replacement of several miles of the remaining original gravity line in this part of the supply system.

Several additional interconnections have been provided between the supply and distribution systems through automatically operated cone valves. In this way much more safety and greater flexibility are made possible in the operation of the water system.

The construction of 14.3 miles of distribution trunk mains throughout the city replaces in many cases wooden mains that had outlived their usefulness and cast-iron mains of insufficient capacity. This general increase in the capacity of the distribution system, along with the installation of 27 additional hydrants in the high value district of the business area, is in line with the recommendation of the National Board of Fire Underwriters. These additional distribution facilities will reduce the insurance rates for the city as a whole some 10 to 15 per cent, affording an annual saving to the citizens of Tacoma in fire insurance costs of approximately $70,000.

The replacement of the present inefficient air-lift system with two or more modern deep wells of equal capacity will increase the dependability of this source of supply considerably and will reduce the power requirements for this operation to less than one-half of what it has been in the past.

In the construction of the booster pumping station to replace the present South Tacoma Pumping Plant at South 62nd and Cedar Streets, the capacity for boosting well water into the high service system will be increased from about 16 or 17 m.g.d. to not less than 20 m.g.d. The efficiency of this station will, of course, be considerably higher than that of the present station, and in the design of this plant, provision has also been made for future remote control of its operation.

The work of the C. C. C. organization in the Green River Watershed will have a lasting and beneficial effect in providing the necessary facilities to protect the timber and young trees in the logged-off area against fire hazards and consequent erosion. This is very important when considering this work in the light of its future effect on Tacoma's present principal source of water supply.

Beautifying of the reservoir sites and control points of the water

system enhances not only their general appearance but lessens the danger from possible contamination and contributes directly to greater facility and ease in the operation of the water system.

The city of Tacoma has materially benefited by the heavy construction program of the Water Department made possible through federal aid. All improvements carried out are of a permanent nature and have been completed at a lower cost to the Water Department than would have been possible under any other method of financing. This construction program in Tacoma has been carried out by the Water Department as one branch of the Utility Department which is under the general direction of Ira S. Davisson as Commissioner of Public Utilities.

Tacoma's New Store and Shop Building

By J. P. Pence

TWENTY years ago the City of Tacoma Water Works stores and shops were housed in a frame shed. This was most inadequate to the needs of the department. In 1922 the Light and Water utilities jointly erected a new concrete fire proof building. This provided the Water Division with twenty thousand square feet of floor space in what was at that time believed to be a modern store and shop building. As Tacoma grew new and greater demands were made of its utilities. The Cushman power project was developed and the Light Division required more and more room for its operations. Our Water Division was also changing and growing. Due to inadequate storage facilities our supplies and equipment were scattered all along our transmission line and in every available Water Division owned building in the city of Tacoma. This was a most unsatisfactory situation. In 1937 the Light Division offered to buy the Water Division half of the building if we would move out. Without any hesitation our superintendent accepted this offer and our Commissioner of Public Utilities obtained the consent of the City Council to sell our interest in the old building to the Light Division and to erect a new one to house our water works stores, shops and offices.

With the legal obstacles out of the way there followed a period of study and planning. Every engineer in the Water Division outlined the needs of his particular department. Our superintendent and engineers visited other water works plants, shops and offices in the northwest and California. They studied the equipment, facilities and practices of these plants and used the information and ideas thus obtained to help plan and equip the new building to take care of the needs of our plant. It was at first proposed to finance the

A paper presented on May 11, 1939 at the Pacific Northwest Section meeting at Tacoma, Washington, by J. P. Pence, Storekeeper, Tacoma Water Dept.

building as a P. W. A. Project. To obtain the allotment of funds from this source requires many months. This gave us plenty of time to work out carefully the plans for the building. After the lapse of a reasonable length of time it began to appear that the Public Works Administration might discontinue loans. Our application for a loan grant on this project was then withdrawn and other financial arrangements were completed. The plans and specifications were all drawn up and the contract let for the building. All plans, designs and specifications were made up by the regularly employed engineering staff of the Water Division under the direction of the superintendent without the aid of outside help.

FIG. 1. Tacoma's New Storeroom

On November 1, 1938 we moved into our new one story all steel and concrete fire proof building (fig. 1). It measures 160 by 245 ft. For details of the floor plan, see fig. 2. A central driveway divides it into two parts, the store rooms on one side and the shops on the other. The building lies north and south with the front to the north. The entrance is 17½ ft. wide by 14 ft. high. This allows the largest auto freight trucks to enter. The rolling steel door to this entrance is set back 20 feet from the outside wall and makes a sheltered entrance way in which the gasoline pump is located. Only one pump is now in place but space has been provided for two. The radiator

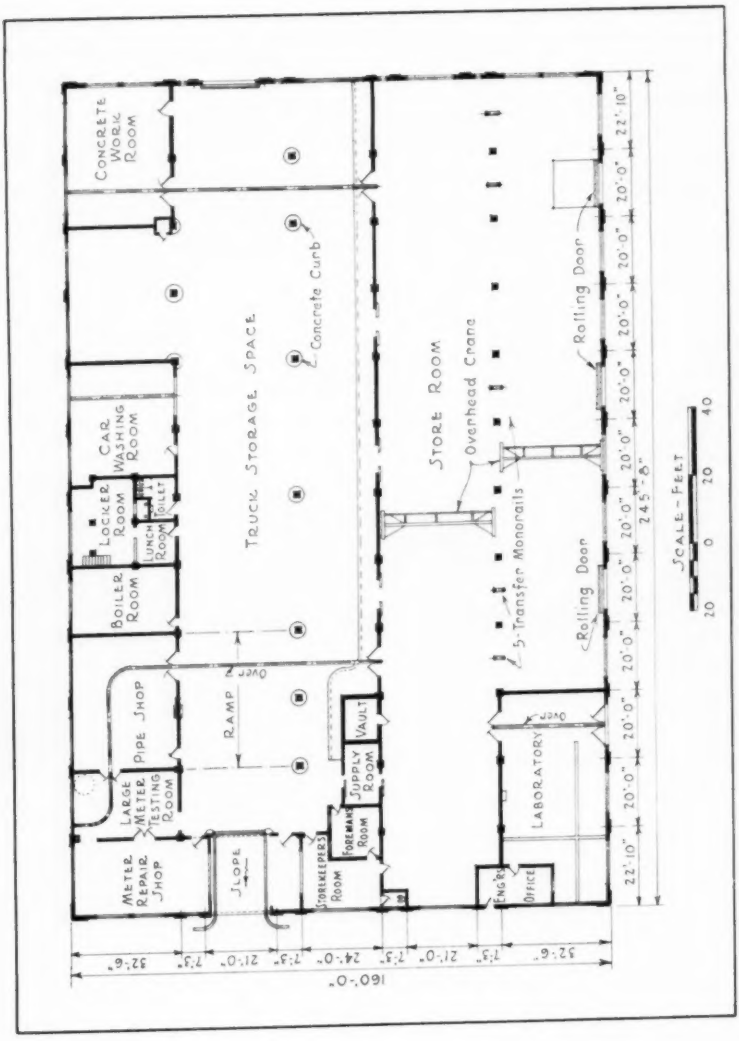

Fig. 2. Floor Plan of New Storeroom

filling water hose in a frost proof well is set in a pit alongside the pump. A vault has been placed under the gas pump base to allow for future connections when a second pump is installed or when repairs are necessary. The gasoline pump is motor driven, registers the total gallons that have passed through it, registers the number of sales and prints on a special form the number of gallons and tenths of gallons delivered at each transaction. The forms are numbered consecutively and the number on the form is the same as the number shown on the gas pump transaction register. The gallons delivered register cannot be reset to zero until one of the forms has been inserted in the slot. This makes the pump fool proof and prevents the possibility of unauthorized operation or the failure of the operating personnel to make the proper record of the dispensing transactions. The pump is padlocked at night and the current for the motor turned off at the switch panel inside the building as a further precaution against loss. A 10,000-gallon gasoline storage tank is installed outside the building under a heavy concrete slab. A 3-inch galvanized pipe filling line runs from this tank to the railroad switching track nearby to provide means for filling from a railroad tank car when desired. A tee and valves are also cut into this line to provide for the connection of another tank in the future. The tank has a manhole through which it may be entered if necessary and a filling plug through which auto truck tank deliveries may be received.

The meter testing and repair shop (figs. 3 and 4) is located in the northeast corner of the building. It has plenty of good daylight. The floor is of $2\frac{1}{2}$-inch vertical grained wood block laid on concrete. The blocks have been treated with a penetrating oil to prevent the absorption of moisture. This makes a very satisfactory shop floor, easy on the feet of the employees and easy to keep clean. The main room is heated by two hot water unit heaters with motor driven air circulating fans. The room is 22 by 33 ft. For night work it is lighted by nine 300-watt blue bowl ceiling lights. It is fitted for two meter test benches and over each of these is a 180-watt Curtis indirect lighting reflector which eliminates all shadows from the test bench. The meter tester is made by the Neptune Meter Company for $\frac{1}{2}$ to 2-inch meters and has been altered by adding a quick closing valve to the inlet line and a bypass through a Ford Flow Indicator Tube on the outlet line replacing the needle valve for stream size

FIG. 2. Floor Plan of New Storeroom

regulation. This flow indicator is very sensitive and registers the flow of a stream from 0.01 to 34 cu.ft. per min. The accuracy of the meter is determined by measuring the volume of water passing through it. This shop is equipped with two steel top work benches, a steel cabinet with some 400 pockets for change gears and other small meter parts, a steel file for cards showing the location of every meter by its street address and an office desk.

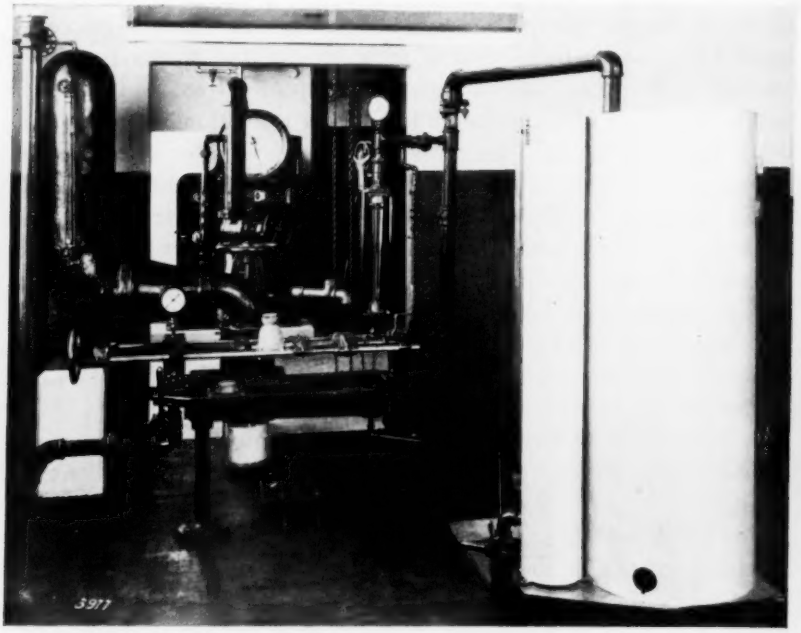

FIG. 3. Test Rack for small meters in foreground with test rack for large meters in rear.

Adjoining the small meter testing room is the large meter testing room 20 by 32 ft. This room is floored with vertical grained wood blocks except for concrete around the test rack. It has a double door opening onto the central driveway for loading and unloading meters. A monorail of the overhead crane system enters it and is so arranged that meters may be moved from the main store room or from trucks in the driveway right into place for bolting the meter flanges to the 6-inch test line. The smaller meters are handled on platform trucks from the driveway to the wash tank, to the repair bench, to the test rack and back to storage. An auto radiator test

tank has been provided and serves very nicely for a meter wash tank. A 12-inch air chamber is installed ahead of the meter on the test line to take up the shock that may result from operating the valves too quickly. The outlet side of this test line is fitted with a 6-inch gate valve around which a 2-inch bypass line is cut. In this 2-inch bypass line is a Clark quick closing gate which is graduated to give a stream opening of from $\frac{1}{8}$ to 2 in. This line discharges into a 1,000-gallon tank mounted on platform scales. The beam of these scales has

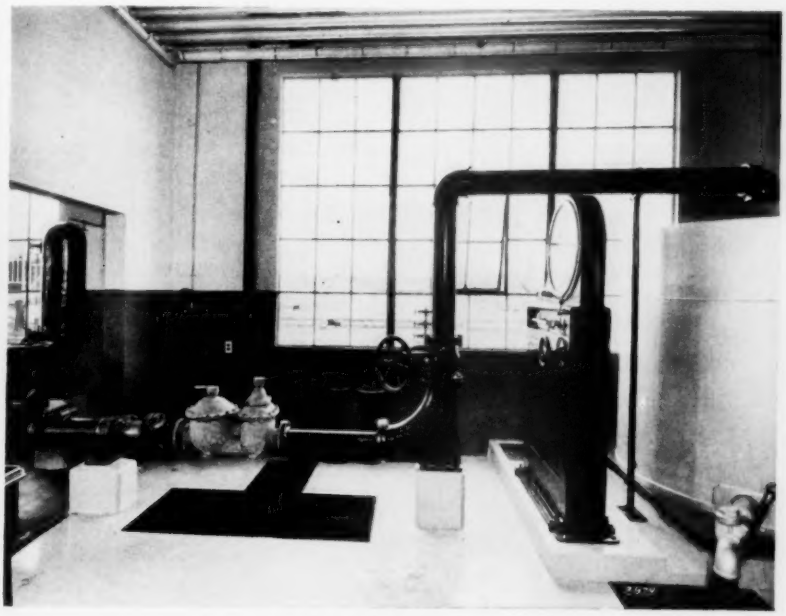

FIG. 4. Test Rack for Large Meters

been removed and replaced with an indicating dial on which is read the error of the meter in percentages slow or fast.

Double swinging doors provide a passageway from the meter shop to the pipe shop. This room also has a wood block flooring and has the monorail crane passing through it to facilitate the handling of large pipe and other heavy pieces. It has double swinging doors opening on the driveway. The elevation of the floor in the shop is 30 in. higher than that of the driveway so that loads may be moved to and from truck beds without having to be lifted or lowered.

A room housing the heating plant is next in the line. All offices

are heated by radiators and the shops by unit hot water heaters with forced air circulation. The heating plant is the hot water type and burns coal. An Iron Fireman Stoker feeds the coal from the bin into the fire box. The heating system is divided into two parts. One part heats the offices and shops which are in use from 8:00 A.M. to 5:00 P.M. The other heats those rooms which are used both day and night. On each part is installed an automatic time switch which turns on the heat only during the hours in which the rooms are in

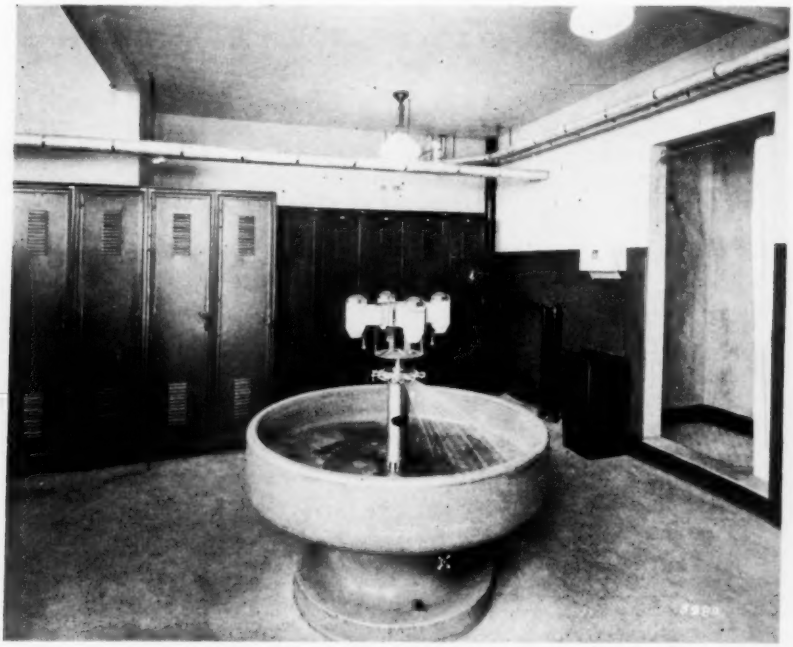

FIG. 5. Lockers and Washroom for Employees

use. They cut the heat off altogether on Sundays. This provides a fully automatic heating system requiring only the removal of clinkers from the fire box and occasional cleaning of boiler flues. In addition to the hot water heating plant the building is wired for electric heat for use in emergencies.

Now comes a section designed and built entirely for the well being and convenience of the employees. First there is a heated lunch lunch room 10 by 12 ft. fitted with a drinking fountain, tables and benches. Back of this is a 19 by 23 ft. locker and wash room (fig. 5).

Steel lockers are provided for the use of the employees. A Bradley Wash Fountain with ten faucets and a 50-inch circular bowl is installed in the center of this room for the use of the men in washing. A two-unit tile floored shower bath with adjustable spray adjoins the locker room. Up stairs on a mezzanine floor is a drying room. This gives the employee a place to hang his clothes and boots in the morning and evening and assures him of dry coats and boots to wear to work in the morning and to put on when he goes home at night. The drying room is equipped with hot water heaters and forced air circulation when the heating plant is in operation. Electric heaters and forced air circulation furnish the necessary heat during the summer months.

The auto wash and grease room is next. This room is 32 by 38 ft. Since we have trucks with long frames and cars with short frames we installed a two post hoist which handles vehicles with either long or short wheel bases. Hot and cold water and air together with the usual set of grease guns, pumps etc. have been furnished for the use of the service man. The floor is concrete coated with an acid resisting paint.

To take care of some of the things that might be overlooked in the planning of the building a space 32 by 40 ft. was left unassigned. This space has given us a place to store pumps, compressors, barricades, and sawdust where they are safe and always accessible for emergency use day or night.

A tower 50 ft. high and 5 ft. square stands next and is used to dry the fire hose.

The last room in this row of shops is 32 by 40 ft. and is used for our cement and precast concrete work. The monorail crane comes into it and provides means for handling and loading heavy meter vault slabs.

Along the storeroom side of the driveway is a platform at the same elevation as the storeroom floor but 30 in. higher than the driveway floor. This enables us to load and unload with hand trucks from the storeroom without any manual rehandling of the load. The monorail crane system also crosses this driveway at two points making possible the use of the crane in handling the heavier pieces. All our cars and trucks have assigned parking spaces between this platform and the driveway proper. Air outlets have been placed on the pillars in front of the parking space and are used by the service man in keeping the tires properly inflated. Along the wall in the rear of

the parking space are convenient outlets for plugging in a battery charger, electric drill or light extension cord. Flood lights are also installed along this wall to light the platform and truck beds during night loading.

At the north end of the building and on the west side of the driveway is the storeroom office. It is located next to the gas pump and the main entrance to the building. It has glass windows on four sides so that a view of a large part of the interior of the building is to be had.

FIG. 6. Shelving for Small Stores

Next to the storeroom office is the foremen's and inspector's office. Both offices have indirect lighting and asbestos tile flooring laid on concrete.

The storeroom itself occupies almost all of the west half of the building and measures 68 by 245 ft. It is divided into two parts by a row of concrete pillars down the middle of the room. The east wall has two sets of swinging and three sets of sliding steel doors opening onto the loading platform in the inside driveway. The

west wall has three steel rolling doors opening onto an outside driveway. The floor level is 30 inches above the driveway at each of these doors and at one of them a pit 14 by 14 ft. has been cut into the storeroom floor to allow a truck to back in and get its load under the crane. Over each half of the floor a bridge crane is operated. These two bridges have connecting monorails and also connect with both monorails running across the driveway into the shops and the one into the engineers' laboratory. The crane system is equipped with a 1-ton electric traveling hoist and a 3-ton hand operated traveling chain block. Both bridges have variable speed propelling motors and carry 330-watt lamps which burn all the time the bridge is in motion and may be lighted while the bridge is not in operation. Safety locking and aligning devices are provided making the system safe even in the hands of a careless operator.

A 10 by 12 ft. fire proof vault opens off the east wall of the storeroom and is used for the storage and safe keeping of a duplicate set of the more valuable records and papers kept in the City Hall Building.

Between this vault and the foremen's office is a delivery room 10 by 18 ft. with a sliding door on one side opening into the storeroom and one on the opposite side opening onto the driveway. A counter runs lengthwise of this room between the two doors. Small articles of supplies and tools are issued over this counter.

In the northwest corner of the building is a room 32 by 62 ft. with an outside swinging door, monorail crane, sink, 6-inch water line and conduit and time switches for installing laboratory checking and testing equipment.

In the rear of the building is our pipe yard. Here we receive, recondition and store both new and reclaimed fittings and pipe on bunks according to its classification. Space has also been provided for the storage of gas-driven shovels and other heavy equipment used in our gravity line maintenance and construction work. A concrete paving makes a U-loop past the ends of each pipe bunk and connects with the driveway through the building on one end and with the driveway along the west side of the building on the other.

All cars and trucks belonging to the Water Division are housed in this building at night except those assigned to employees who are subject to call twenty-four hours of the day. The auto service man is held responsible for the oiling, greasing, battery and radiator filling, washing, checking air in tires and minor repairs. All servicing is

done at night. The drivers fill their gas tanks when they come in in the evening.

The stores and supplies are handled by the storeroom personnel. When a man wants something he comes to the storeroom office and gets a requisition. The requisition is written in the office because it must show these three things: an itemized list of the supplies wanted, the work to which they are to be charged, and the street address of the location at which they are to be used. These three notations enable the storeroom to make the posting to the stock cards, give the accounting department the necessary information to charge the costs to the proper job and give the engineers sufficient information to check thoroughly the charges against their respective work orders when they are completed. The employee takes the requisition from the storeroom office to the delivery room where the issue is made and the requisition is signed by the man receiving the supplies and by the man issuing them. After being filled it is returned to the storeroom office where the cost of each item is entered on it and the proper entries made on the stock record cards. One copy of the completed requisition is filed at the storeroom and the original is forwarded to the accounting department at the City Hall. The stock record account is kept on a Kardex system which shows a perpetual inventory of the stock both in quantity and in value. The figures are checked monthly and the quantity figures once each year at the annual inventory. The storekeeper is in charge of all work carried on in the shops, storeroom and yard and is held accountable therefóre to the superintendent.

The Water Division of the City of Tacoma with W. A. Kunigk, Superintendent, is a part of the Public Utilities Department operated by Ira S. Davisson, Commissioner of Public Utilities.

ABSTRACTS OF WATER WORKS LITERATURE

Key. 30: 402 (Mar. '38) indicates volume 30, page 402, issue dated March 1938. If the publication is paged by issues, **30:** 3: 402 (Mar. '38) indicates volume 30, number 3, page 402. Material inclosed in starred brackets, ***[ ]***, is comment or opinion of abstractor. Initials following an abstract indicate reproduction, by permission, from periodicals as follows: *B. H.—Bulletin of Hygiene (British); C. A.—Chemical Abstracts; P. H. E. A.—Public Health Engineering Abstracts; W. P. R.—Water Pollution Research (British).*

MAINS AND HYDRANTS

Elastic Properties of Cast Iron. Alexander I. Krynitsky and Charles M. Saeger, Jr. J. Research Nat. Bur. Standards **22:** 191 (Feb. '39). *Also* **New Method of Measuring Deflection in the Transverse-Loading Test of Cast Iron.** Bul. A. S. T. M. No. 97: 23 (Mar. '39). One of most important det'ns, to be made in the transverse-loading test of cast iron is deflection, particularly true in case of newly developed high-strength cast irons. Term "elastic properties" taken to mean those complex properties that determine behavior of c.i. under load. All properties related to, and to a large extent, detnd. by structure. Composition, shape, size and surface condition of specimen of greater importance in determining properties of c.i. than in steel and other metals. Det'n. of elastic properties complicated by fact that even moderate stresses produce plastic as well as elastic deformation. For det'n., complete stress-strain curves obtained by applying loading in progressively increasing steps, determining total deformation under each load and the permanent set or plastic deformation after the load has been removed for each step. Difference between the two considered elastic deflection of bar. Deflection in this investigation measured by new method in which rubber band is stretched tightly along length of bar and held in position by 2 clamps 18″ apart, having metal strips on inner surface to keep rubber band near to, but not in contact with, surface of bar at all times. For reference mark small piece of paper cemented to bar midway between supports. Deflection equals distance between straight line of band and upper edge of this reference mark as measured through a micrometer telescope 20″ away and independently mounted. Accuracy of measurement—0.002″. Properties of three types c.i. determined by measurements under transverse-loading; (A) stove-plate pig iron to which 10% basic open-hearth ingot iron added, (B) medium cylinder type, and (C) soft iron used for general castings. Compositions of irons (A), (B) and (C) respectively were: total carbon 3.44, 3.79, 3.44%; silicon 1.40, 1.40, 2.43%; manganese 0.15, 0.63, 0.77%; phosphorus 0.46, 0.81, 0.395%; sulfur 0.020, 0.062, 0.050%. Four melts of each iron made, heated to predetermined max. temps. of 1400,

1500, 1600 and 1700°C. respectively and each melt poured at temps. corresponding to 100, 150, 200, and 250°C. above temp. of the liquidus for that particular iron. Total deflection at breaking load and "set" of each bar under increasing step loadings detnd. with elastic deflection taken as difference between total and plastic deflection for each load. Deflection plotted against load. Curves obtained all smooth with absence of scatter in results. Shown that elastic deflection curve is linear only in its lower portion; for iron (A) linear portion extends to some point between 1400 and 1800 lbs. for each specimen; for irons (B) and (C) it extends to range of loads from 1200 to 1400 lbs. Above linear portion each curve inclines toward deflection axis. Term "relative modulus of elasticity" used in place of "modulus of elasticity" because latter term applied to c.i. generally means relative stiffness of iron under particular conditions of loading. Relative modulus of elasticity as detnd. in the transverse test for a single centrally applied load, detnd. by formula $E = \frac{Pl^3}{48ID}$. E = relative modulus of elasticity in lbs. per sq. in., P = load in lbs., l = span in inches, I = moment of inertia, and D = deflection (at load P) in inches, E_1 for straight portion of curve determined, also E_2 for second portion of curve at point of rupture. E_1 consistently higher than E_2; for irons (A) and (B) difference between E_1 and E_2 generally greater than 1,000,000 lbs. per sq. in., usually less for iron (C). In general, values for E_1 for iron (A) higher than for other irons, and under some conditions of pouring, values of E_1 for iron (B) higher than for iron (C). Believed that the relative modulus of elasticity, determined from the straight portion of the curve, expresses more accurately the elastic rigidity of c.i. than does the secant modulus, determined from the slope of a straight line drawn from the origin to a point on the curve. Bibliography of 18 articles included in first reference.—*Martin E. Flentje.*

Effect of Vibrations on Pipes. Siegfried Clodius. Gas-u. Wasser. **82:** 285 (Apr. 29, '39). Tests are under way in Dresden to study the effect of vibrations on pipe lines. Quickly acting impact forces may cause breaks, whereas vibrations of long duration may have a fatigue effect on the joints. The tests will be made on 12″ pipes with various materials for joint filler, vibrated with amplitude of one millimeter and frequencies between 10 and 40 cycles per second. Investigations in Stuttgart have shown that such frequencies are the ones most often transmitted as they correspond to the frequencies of the soil. Preliminary tests on joint fillers at Dortmund indicate that leaf aluminum is least resistant to the influence of vibrations, aluminum wool and Sinterite are better, but lead is best. ★[Rubber and sulfur compounds have not been tested]★. This corresponds to tests of the elastic properties of the joint ring itself, where leaf materials formed a much stiffer ring than wool materials.—*Max Suter.*

How Much Does it Cost to Make a Main Extension? D. R. Taylor. W. W. and Sew. **85:** 1047 (Nov. '38). Tabulation of cost estimates of main installations for various pipe sizes; trench widths, depths, and cover; labor and materials; and overhead; for rapid estimation of main laying costs.—*H. E. Hudson, Jr.*

Buried Pipes Made to Talk Back. ANON. Eng. News-Rec. **122:** 783 (Jun. 8, '39). Radio signal device, known as "pipe anticipator," for attachment to any type of excavating machine, which warns operator, visually or audibly, of buried pipes or cables has recently been perfected by Charles I. Maust of The Public Service Gas and Electric Co., Newark, N. J. Device may be used also on tunneling, boring and pushing machines, dredging and mining equipment and in marine salvaging operations. Precision is not affected by size or depth of pipe or cable, or material of which they are made, providing it is metallic. Mechanism is adjusted to give constant supervisory signal, which automatically increases in intensity as hidden pipe is approached. It is immune to all electrical interference. Ability to operate device is easily acquired and its use permits more rapid excavation.—*R. E. Thompson.*

A Case of Fatal Gas Poisoning in Welding in a Closed Tank. R. J. WRIGHT-SMITH. J. Indust. Hyg. & Toxicol. **21:** 24 ('39). A well built, healthy man was engaged upon welding steel frames in the after peak of a ship. He was working in an unventilated tank, measuring 10′ x 17′ x 15′. He began work at 7:45 a.m. and continued until 4:30 p.m., when he complained of sickness. At 6 p.m. he began to cough and vomit and was gasping for breath. He was removed to hospital where he died next morning. The lungs were large, red and intensely oedematous. Death was certainly due to inhaling a poisonous gas; probably nitrogen peroxide was responsible. This gas is known to be formed in the electric arc from the atmospheric gases. But the possibility that death was caused by phosgene is also considered. Salt water may have left sodium chloride on the plates of the tank, from which chlorine could have been liberated to unite with any carbon monoxide formed. The symptoms would agree with poisoning by either gas. Use of the electric arc in confined, unventilated spaces is to be deprecated.—*B. H.*

Water Main Cleaning. THOMAS B. RAY. W. W. & Sew. **85:** 753 (Aug. '38). Corrosive waters create need for occasional cleaning. At Skowhegan, Maine, heavily tuberculated water system was cleaned by sending a mechanical scraper through the pipes, propelled by water pressure. Procedures for cleaning both by the cable method and the pressure method are described. Excellent results were obtained. Treatment of the water to prevent corrosion has been commenced. Cleaning of a long transmission main is described. The value of "C" was raised from 57 to 130. Experience with successful chemical cleaning, using inhibited acid, in a 1″ steel pipe is described. Difficulties with the treatment and suggestions for further use are presented.—*H. E. Hudson, Jr.*

Cleaning Mains with Big Air Bubbles. ROSCOE R. HOWARD. Pub. Wks. **70:** 2: 14 (Feb. '39). While water leaving Slater, Mo., partial softening, Fe removal and purification plant does not affect mains, well water coming to plant, through deposition, reduced capac. of 2 mi. of 8″ pipeline to that of 5″ line, raised head from 50′ to 90′ and reduced pumpage greatly. Mechanical home-made scraper cleaned pipe fairly well lowering head from 90 to 78 lbs.,

which however again increased to 85 within 3 yrs. Second cleaning carried out with compressed air at 100 lbs. pressure introduced in impulses of bubbles at rate of about 2 per min. Method cleaned pipe easily and quickly; to be tried out later on city distribution system.—*Martin E. Flentje.*

New Processes for Cleaning Encrusted Pipes. ANON. Zbl. Bauverw. **58:** 618 ('38); Gesundheits-Ing. **61:** 590 ('38). Two new processes used in Sweden for cleaning pipes are described. By the "Ingo" process sand is carried through the pipes by a strong blast of air. By the second process the pipes are filled with hot and cold air alternately; the expansion and contraction of the pipes loosens the deposit which is swept out by the air.—*W. P. R.*

Hydrant Standardization. SIEGFRIED CLODIUS. Gas-u. Wasser. **82:** 124 (Feb. '39). Govt. decrees require German waterworks to arrange for interconnections for use in time of need, installation in dist. systems of numerous valves and use of pipe with not less than 100 mm. diam., except under unusual circumstances; maintainance of pressures to allow fire fighting without pumpers by having pressure at the roofs of allowable buildings of 2 atm. Flush hydrants offer certain advantages, one being the lesser danger of destruction by bombs, stream-lined valves are recommended and where possible hydrants should be in staggered locations on opposite sides of streets. Regulations issued requiring standardization of hydrants affected approx. 200 different types of hydrant being used in Germany. Numerous illustrations and information given on methods of installation, materials to be used and allocation of costs for change to standard installation.—*Martin E. Flentje.*

Marking Fire Hydrants Neatly and Permanently. W. M. RAPP. W. W. and Sew. **85: 772** (Aug. '38). Water main size may be stamped on a boss on the fire hydrant cap to inform firemen of water availability.—*H. E. Hudson, Jr.*

SUBMARINE PIPE LINES

River Crossings for Water Pipes. ANON. Eng. News-Rec. **121:** 826 (Dec. 29, '38). There are 29 river and canal crossings in Indianapolis distr. system: in 17, pipes are laid under water with 3′ of sandy gravel cover, and in 12, lines are carried on bridges. Under-water crossings are carefully inspected annually. Bleeders are provided on uninsulated bridge crossings 12″ and under in diam. to maintain velocity above 0.5′ per sec. in zero weather, this rate being determined largely by experience. Four methods of insulation are employed for bridge crossings: (1) Boxing and covering with 4–6″ of sawdust. This is cheapest and is satisfactory where sawdust can be kept dry. (2) Three 1″ layers of animal hair laminations with covering of tarred felt paper. (3) Three layers of corrugated asbestos insulation wrapped with felt saturated with asphalt. (4) Rock and cork concrete, 3″ thick, inner 2″ being largely of cork, with ½″ space around pipe to provide dead-air insulation. None of crossings froze during severe winter of '36 but a few mains with inadequate cover gave trouble. Mains are laid with 3½′ cover. Subsoil is sand and clay.—*R. E. Thompson.*

Water for San Francisco Via Submarine Lines. N. A. ECKART. W. W. Eng. **91**: 1221 (Sep. 14, '38). 7 lines of submarine pipe have been laid across lower arm of San Francisco Bay, approx. 21 mi. S. of city. Crossing about 6500′ with max. water depth some 700′(70′?), adjoins Newark Slough which is 400′ wide and 15′ deep. Lines include 2-16″, 2-22″, 1-42″, and 2-54″ laid in '36. Latest line carried partly on bridge structure and then into trench on bottom, pipe welded steel flanged joint construction, cost $700,000.—*Martin E. Flentje.*

Operations on Under-River Pipe Line at Bath, Me. MAURICE A. LIBBY. W. W. and Sew. **86**: 103 (Mar. '39). After a brief description of the Bath water system, the author describes a break in the submarine main in mid-winter. Difficulties due to ice-flows immensely complicated the urgent repair work. Aid from the U. S. Coast Guard, State Dept. of Health, Portland Water District, and a salvage firm was enlisted in getting the repair done promptly. Reliance temporarily placed on an emergency well supply. Repairs on the submarine main were finally completed. Within 24 hrs., repair job gave out and had to be replaced once more. Pressure was finally restored just as emergency supply was exhausted. A new pipe line is being installed to supplement the trouble-maker.—*H. E. Hudson, Jr.*

Subaqueous Pipe Line Serving Hancock, Michigan. ANON. Am. City **54**: 4: 81 (Apr. '39). A 1320′ subaqueous line across Portage Lake was laid. A clam shell derrick scow dredged a trench with a max. depth of 15′, min. depth of 1′ and 4′ width at bottom. Three 20′ lengths of pipe connected by Dresser joints were floated to a compressed air station and tested for leaks under 80# pressure. They were then floated to a derrick scow where with appropriate equipment they were put in place in the trench by a diver. Each length of pipe had 3 mudsills bolted to it. After connecting, the water was blown from the line and an 80# air pressure test started. In addition to watching the air gage, the line was patrolled to watch for bubbles. Not one leaky joint was found. Concrete anchors were constructed on the shore when the line was complete, and then the line was tested under 310# pressure.—*Arthur P. Miller.*

LEAKAGE AND WASTE

Some Experiences in Stopping Leaks of Water and Dollars. FRANK J. BROZ. W. W. and Sew. **86**: 75 (Feb. '39). Cicero, Illinois, maintains a permanent underground leakage survey, periodical plumbing inspections, good meter maintainance, careful choice of meter size, inspection and periodical testing of all meters, metering fire-line services. Two plumbers employed to make continual inspections. Small meters tested every 5 years, large ones annually. Meter size choice based on recorded flow curves. Unaccounted for water has been reduced from 46% to 20%. Battery meters used on all services 3″ and larger.—*H. E. Hudson, Jr.*

Water Losses in Small Plants. EDWARD WENGER. Gas-u. Wasser. **81**: 744 (Oct. 15, '38). Measurement of water losses is often difficult. The differ-

ence between the master meter and total of individual meters gives only a rough indication. Control of losses can be obtained by following methods: Observations of the levels in the high storage tank should give similar results for the same week nights. Measurements of the night consumption (10:00 P.M. to 6:00 A.M.) shows large losses quickly. The rate of night flow gives an indication of losses in distribution system. All plants should be arranged to allow these measurements. If we call the percentage of losses x, sales recepts from water s, cost of water c and earnings e, then we have

$$e = s - \frac{100\,c}{100 - x}$$

If x is large, the earnings disappear. Losses must therefore be kept small. Efforts to reduce the losses pay.—*Max Suter.*

Reducing Water Waste in a Metered System. TIMOTHY W. GOOD. Am. City **53:** 11: 68 (Nov. '38). In Cambridge, Mass., the water meter readers also make inspections of fixtures to determine leakage. In '37 they detected 2249 leaks and 152 were reported by others. Authority for the meter reader to make these inspections is contained in a city ordinance. Water use is checked, too, to see if a user takes more than 10% in excess of amount used in previous quarter. If that happens, the user is notified to repair the leaks on his premises. Except for underground leaks, it is estimated that the others found in '37 would have wasted 2¼ m.g.d. if permitted to continue.—*Arthur P. Miller.*

Water Wastage and Metering. H. J. TILL. Surveyor (Br.) **94:** 384 (Oct. 7, '38). *From paper presented at 9th. An. Conf. of So. African Dist. of Inst. of Munic. and County Engrs. of Johannesburg.* Metering is best method of preventing waste. Routine inspection is essential as consumers are known to be inattentive to leaky plumbing. Meters quickly reveal occurrence of leaks. The Johannesburg Council charges only cost price for water known to have been lost through leaks. Wastage of water on the main side of the meter is controlled in Johannesburg by periodic checks of the reticulated area. Method pursued now includes: (a) regular patrol of four men who listen at valves for leaks; (b) maintenance of records of leaky mains so that they may be slated for renewal, (c) clerical check on meter readings, (d) renewal of meters after reasonable life. The disc type of meter has replaced the older positive, piston type, but at present the British rotary piston meter is displacing the American type of disc meter.—*H. E. Babbitt.*

DISTRIBUTION STORAGE

Remote Control Operation of Pressure Equalizing Stations at Oklahoma City. A. E. WATJEN. W. W. & Sew. **85:** 535 (May '38). Two equalizing tanks of 1 mil. gal. capacity each are situated too low to ride on the distribution system. It is necessary to control them to prevent overflowing during high pressure periods and to pump out of them at times when the pressure drops. The control equipment, which is situated in a pumping station 5½ mi. distant from each tank, centralizes operation control. For each tank, there is a

level recorder, a distribution system pressure recorder, telephone set, and selector dial (like dial telephone) control switch, located in the central station. Controls are interlocked to eliminate operation mistakes, and to maintain fairly uniform pressure. Operation of the system is described and illustrated.

Experiences in Design and Operation. M. B. CUNNINGHAM AND FRANK HERRMANN. *Ibid.* p. 539. Installation of twin surface tanks was about equal to one elevated tank in cost. Electric wiring diagrams for remote control are shown and the functioning of the system is explained. Considerations in design and equipment selection are discussed, and some improvements are suggested.—*H. E. Hudson, Jr.*

Pumps to Meet Peak Demands. D. D. GROSS. Eng. News-Rec. **122:** 790 (Jun. 8, '39). Objections to erection of elevated tanks in residential district of Montclair, suburb of Denver, Colo., necessitated other means of providing adequate supply and pressure during peak consumption periods. Recording pressure gages were attached to hydrants and from records obtained and analysis of consumption data, reservoir filled during night to supply pumping station operated during day was decided upon. Construction is now underway on 5-mil. gal. reinforced concrete box-type reservoir, in natural depression, and adjacent pumping station equipped with 2 pumps, 5- and 10-m.g.d. capacity. First cost will be lower than elevated storage but operating cost will be higher.—*R. E. Thompson.*

Elevated Tank at San Diego Reduces Pumping Costs. ANON. W. Cons. News **14:** 137 (Apr. '39). A 500,000 gal. elevated steel tank and connecting pipe-lines, with total cost near $70,000, erected recently in eastern portion of San Diego. Tank 50′ diam. with ellipsoidal proof and hemispherical bottom, high water line 71′ above concrete footing, range in head 40′. Design based on, among other requirements, factor of safety of 4; horizontal wind pressure of 20 lbs. per sq. ft. of exposed area when less than 40′ above ground, 30 lbs. above 40′, with 0.6 of curved area effective; earthquake stresses due to a force of 0.1 gravity; tension on net section of tank, bottom and lower shell 10,000 lb. per sq. in., upper shell rings and roof, 12,000 lbs. per sq. in. Tank completed May 14, '38.—*Martin E. Flentje.*

Southend Water Supply. New Water Tower at Billericay. ANON. Wtr. and Wtr. Eng. (Br.) **41:** 255 (May '39). The height of the tower to the bottom of the tank is 37′-6″. Tower is of reinforced concrete with 8 legs. Tank is of reinforced concrete, 41′-9″ inside diam. and 12′ deep. The total height of the structure is 55′-6″.—*H. E. Babbitt.*

Corpus Christi Builds a Covered Reservoir. CHARLES TERRELL BARTLETT. Eng. News-Rec. **121:** 727 (Dec. 8, '38). New 10-mil. gal. reservoir and waterproofing of same are described. Reservoir is bowl shaped basin in which sand and clay taken from central excavation were used to build encircling embankment. Reinforced concrete roof consists of groined arches formed by intersecting barrels of 3 series of arches set at 60° angles. Earth cover is 15-27″ deep. Inside top diam. of concrete lining is 266′ and water depth at

center 34′. Complete system of underdrains under floor. Contraction joints between lining slabs were "cold joints" with groove 3″ deep, cast in second slab poured, tapering from ¾″- width at surface to ½″ at bottom. To meet demand for water, reservoir was placed in service during summer prior to sealing joints, which was effected later. Original type of joint planned, cement and oakum as in cement joints for water mains, proved unsatisfactory. Cement and oakum were removed from most joints, and latter were cleaned and made up with oakum and hot coal tar and then covered alternately with 3 coatings of hot coal tar pitch and 2 of waterproofing fabric. Remainder of slab areas treated with 3 applications of neat cement grout containing small amount of waterproofing admixture and finally some 3 tons of bentonite powder sprinkled over whole area of reservoir. Test showed no observable leakage up to 11.6′ below full level and 7,400 gals. per day at full level.—*R. E. Thompson.*

Reservoir Lining Cracks Sealed with Bentonite. ANON. Eng. News-Rec. **122:** 450 (Mar. 30, '39). The 3-mil. gal. reservoir on Yerba Buena Island, which provides gravity water supply for Golden Gate International Exposition, is located on steep side hill. After excavation, bottom (50′ x 220′) was covered with 6″ layer of concrete and sides (½:1 slope) were lined with 4″ of shotcrete around wire mesh. When reservoir was placed in service, serious seepage losses occurred. No cracks were visible on unwatering and it was concluded that leakage was occurring through hair cracks that opened under water pressure. Decided to attempt to stop leaks with bentonite, which could be applied while reservoir was full. Powdered bentonite, passing 200-mesh screen, was mixed in 3-gal. batches, using ⅛ lb. per gal., and introduced through 1″ pipe extending through holes in wooden roof to within few inches of bottom. Within 3–4 days after treatment, seepage loss decreased from 9000 to about 2000 gals. per day and in succeeding 7 mos. showed no tendency to increase. About 100 lbs. of bentonite was used.—*R. E. Thompson.*

Cathodic Protection of an Elevated Tank. O. B. HESS. Ann. Rept. Ohio Conf. Water Purif. **18:** 109 ('38). Cathodic protection has been adopted for preventing corrosion of 200,000-gal. elev. steel tank at St. Clairsville. Apparatus consists of rectifier connected to 110-v. a. c. circuit and polished stainless steel electrode 1.25″ diam. and 15′ long suspended in center of tank. Current flows from electrode to tank, which is grounded at bottom of riser. Gray film forms on surface, under which metal is clean and bright. Cost of equipment $325 and operating cost approx. 40¢ per mo., which will be considerably reduced when tank is thoroughly clean.—*R. E. Thompson.*

Steel Surfaces Cleaned and Prepared for Painting by Means of Chemical Reaction. CARLETON CLEVELAND. Products Finishing **3:** 7: 46 ('39). For removing mill scale and preparing surface for painting, plates to be used for manufacture of steel tanks are placed prior to fabrication first in vat of dilute sulfuric acid of desired temp. for specified time, rinsed, dipped in water of same temp. as acid and finally placed in third vat containing hot solution of phosphoric acid and iron phosphate, which forms thin coating of iron phos-

phate on steel. Immediately after removal, plates are painted with special red lead and graphite paint. Painting while hot has advantages of reducing drying period and increasing bond.—*C. A.*

A Water Tower A-Fire. J. F. RENY. W. W. and Sew. **85:** 978 (Oct. '38). During repainting operations on Portland, Maine, standpipe, bituminous enamel caught fire. Standpipe, 46 years old, was uninjured. After cleaning it was repainted and put back into service.—*H. E. Hudson, Jr.*

WATER WORKS—GENERAL

Good Design and Operation Characterize Greenwood, S. C., Water Works. ANON. Am. City **54:** 3: 52 (Mar. '39). Greenwood, S. C., 11,000 pop., has 3 sources of water. The main one, Coronaca Cr., 5 mi. from city, an auxiliary one, Rocky Cr. near the plant but carrying considerable pollution, and several wells near the plant the water from which is so high in CO_2 that they are not used. Distr. system in city is of c.i. except for some 2″ galv. steel. Services are practically 100% metered. Filtration plant, constructed in '36, is located in Oak Hill Park where the city is developing a golf course. Water enters plant from a 16″ pipe into a flume over which are mounted 2 dry feed chemical machines for supplying alum at rate of 0.75 to 2.5 g.p.g. Plans have been made to prechlorinate and pre-ammoniate the raw water but at present only chlorination of filtered water on the way to clear wells is accomplished. Outside of filter building a double flume with over and under baffles provides 30 min. of mixing and then leads water into coagulating basins through a stilling wall. A separate pump in filter building is capable of transferring water from one coagulation basin to the other or to mixing flume. This permits saving water in a basin when it is to be cleaned. After coagulation, water flows over stilling wall to 2 filters, each of ¾ m.g.d. capac. but operated at ½ m.g.d. Filtered water goes to a single header where chlorine is added at rate of 0.2 p.p.m., and following chlorine application 0.9 g.p.g. of lime is added to reduce corrosive quality. On the service to the city 2–400 g.p.m., 1–600 g.p.m., 1–700 g.p.m. and 1–1500 g.p.m. pumps are connected into the clear well. A laboratory equipped to do necessary chemical and bacteriological work is included in plant.—*Arthur P. Miller.*

Surface Water Use and Purification in Florida. ANON. Pub. Wks. **70:** 5: 11 (May '39). Of 242 public water supplies in state, 222 are from wells, 9 from lakes, 4 from rivers, 4 from canals and 3 from springs. Of well supplies 169 are not treated, 8 are aerated, 21 have no treatment except aeration and chlorination, remaining 24 receive some additional treatment. All except one of surface supplies treated. Ft. Pierce and Tampa have complete treatment plants; latest plant to use surface water (Bradentown, pop. 7500) described in article.—*Martin E. Flentje.*

Practices of Akron, Ohio. NATHAN N. WOLPERT. W. W. Eng. **92:** 182 (Feb. 15, '39). W. R. LaDue is Sup't. and Chief Eng. of water dep't. Fire hydrants owned and repaired by dep't., inspected by city Fire Dep't. Hy-

drants set 15–20′ back from street and practically all have valve on branch. Copper used for services, however only in ¾″ and 1¼″ sizes, above that 4″ c.i. pipe used. Lead substitutes used for new pipe joints, both substitute and lead used in repairing joints. New mains tested for leakage, 100 gal. per in.-mile per 24 hrs. allowed under pressure about 45 lbs. above working pressure. New mains sterilized by hypochlorite. Dep't. will spend up to $200 for each new customer or extension, if cost higher, excess must be paid or definite return on whole guaranteed. Standby charge for sprinkler service based on size of line and size of detector check valve. Meters read every 3 mo., one of 3 districts read every mo. Metered connections,—56,000; meter readers and repairmen total 11; av. reading is 175 per day. Meters brought to shop when about 748,000 gal. registered. Duplicate set of service records kept, one in shop office and one in main office. Most complaints are of size of bill.—*Martin E. Flentje.*

Maintenance and Repair Methods—Cincinnati, Ohio. NATHAN N. WOLPERT. W. W. Eng. **92:** 977 (Aug. 2, '39). Water supply of Cincinnati (pop. 475,000) taken from Ohio R., filtered and treated. Sup't. is Carl A. Eberling. Customers pay for service pipe, copper used up to 2″, c.i. above that, all services laid under 3.5′ of cover. 14–2 man valve crews employed. Hydrants placed 500′ apart, at present are placed on 6″ branch. Water sold outside city at 50% higher than city rate. Meters purchased by consumer, after purchase kept up by dep't., meters tested at pressures 170 and 60 lbs. for high and low service respectively. Water rates start at 10¢ for first 60,000 cu. ft. monthly, 9¢ for next 440,000, 8¢ for next 500,000 etc. down to 5¢ for excess over 3,000,000 cu. ft.—*Martin E. Flentje.*

Water Practices of Louisville (Ky). NATHAN N. WOLPERT. W. W. Eng. **92:** 850 (Jul. 5, '39). Louisville Water Co. practices reviewed. No services connected on mains 24″ or larger; copper used for standard service, company paying for same from main to property line within city limits; av. cost of ⅝″ service is $17.87, ¾″—$24.13, 1″—$29.18, 6″—$196.33. Meters placed in vaults, av. cost of ⅝″ vault is $8.52, ¾″—$9.00. Services placed with 3′ cover, mains 3′ and 3½′. Super-de Lavaud cement lined c.i. pipe in 18′ lengths used, joints made with dry braided jute and leadite. Av. costs of repairing leaks and breaks on 4″, 6″, 8″ and 20″ mains are respectively $61.53, $63.56, $89.28 and $389.38. Hydrants made part of Fire Dep't's. operations, inspected monthly, no. in use totals 3500. New extensions made without charge if revenue equal to 15% of cost. Meters owned by company, ⅝″ meters taken out for test after service of 5 yrs., 1″ and 1½″ meters tested yearly. In '38, 17,994—⅝″ to 1″ meters tested at av. cost of 13¢ for labor and overhead; 1081—1½″ and larger meters tested at av. cost of $1.55.—*Martin E. Flentje.*

Indiana State Bureau of Sanitary Engineering, Annual Report, '37–'38. B. A. POOLE, *Chief Eng.* On Jul. 1, '38, Indiana had 308 public water supplies, serving pop. of 2,013,822. Of this number, 1,184,105 used water from 47 surface supplies, of which 3 were of questionable or unsafe character. 102 of 261 ground water supplies chlorinated. Pop. served with ground water—612,599;

217,118 inhabitants use untreated public well water supplies. Water from 191 supplies examined for fluorides, 32 had content of 1.0 p.p.m. or more, 65 between 0.1 and 0.9, and 94 had none. Only one supply (Lowell) had over 2.0 p.p.m., where conc. of 5.0 p.p.m. found. Many Lowell children found with mottled enamel. Supplies of state, pop., ownership, source and treatment given in tabular form.—*Martin E. Flentje.*

Selling Water in Paradise. CHARLES E. HOGUE. W. W. Eng. **92:** 972 (Aug. 2, '39). Water supply of Honolulu, derived from wells, comes well within limits of bacterial quality of U. S. Public Health Service standards without chlorination or other treatment. Operated by public Board of Water Supply with Frederick Ohrt as Chief Eng. and Mgr. Works today valued at more than 10 million dollars, includes three main steam pumping stations, 9 electric booster stations, 2 aerators, 19 concrete reservoirs, 6 tanks, has 300 mi. of mains, 1900 fire hydrants, serves 21,000 customers. Supply obtained from 5 artesian areas and from springs and tunnels in the Koolaus, a serrated, precipitous range of hills behind city. Slogans of dep't. are "Conserve Water" and "Pure Water—Man's Greatest Need." Illustrations given of public relations work carried on.—*Martin E. Flentje.*

The Amplification of Queensland's Water Resources. J. J. C. BRADFIELD. Civ. Eng. (Br.) **24:** 46 (Feb. '39). The Great Artesian Basin of Australia has an area of about 600,000 sq. mi. of which 370,000 occupy slightly more than half of the area of Queensland. The water which comes from the eastern edge of the Basin is diminishing in flow at a rate of about 2% per annum, so that by about 1958 water from wells in this aquifer will have to be pumped and the conservation of water will become necessary. Annual rainfall of Queensland varies from 165″ in the north coastal region to less than 5″ on the western frontier. Region of lowest rainfall coincides approx. with the Great Artesian Basin. Due to over cultivation the moisture which was originally returned to the air by vegetation in the coastal belt is now lost. Dew-fall has lessened while evaporation, aridity, and runoff have increased and there is reason to believe that rainfall has decreased. Diversion of flood waters and a portion of the normal flow of the coastal rivers at Tully falls, with a watershed of 180 sq. mi. would be the first step in ameliorating conditions. At this point a dam should be constructed about 700′ long and 120′ high. Another dam might be placed at the Falls of the Herbert River with a catchment area of 2,038 sq. mi. Here a wall 100′ high and 1,000′ long can be constructed to form an adequate reservoir. From this site a constant flow of 3,000 c.f.s. could be diverted into the Burdekin River near Wairuna, a distance of 13 mi. with a fall of 46′. Flood waters could be collected by a dam at Hell's Gates on the Burdekin River, with a catchment area of 7,204 sq. mi., allowing for a constant flow of 6,000 c.f.s. A series of large basins could be established on the Flinders River, which could be used for ground water replenishment. The various water courses, some 600 mi. in length, would be reconditioned and the beds, where required, lined with reinforced concrete to minimize seepage. Benefits would include increased water supply, irrigation to a vast region, possibilities of hydro-electric power, and the escape from an annual monetary loss of 1.5

million pounds sterling due to loss of sheep pasturage and possibly 2.5 million pounds sterling due to loss of cattle grazing areas, to say nothing of other great losses. The scheme will cost not less than 30 million pounds sterling.—*H. E. Babbitt.*

Water Supplies of Malaya. R. L. NUNN. Surveyor (Br.) **95:** 3 (Jan. 6, '39). Water supply difficulties in Malaya are due to financial and other local problems rather than lack of water in a region with an annual rainfall of 90". Principal problems are in the coastal regions. There is no water-bearing geological formation but the surface strata will, when rainfall is plentiful, supply a limited quantity in surface wells. In general, however, wells as a source of a public water supply are a failure. Surface water supplies from rivers must be purified and the construction of purification plants is now the practice. Chemical treatment and mechanical filtration are depended on when they can be supervised, chlorination being used as a barrier. A comparatively recent innovation in Malaya is the use of ammonia. Health Department of the Federated States conducts regular bacteriological testing of doubtful water supplies and of filtration plants. Materials used for distributing pipes include cast iron, asbestos, and concrete. Rate of water consumption varies between 30 and 50 gal. (Imp.) per cap. per day but 100% metering has not yet been attained. Considerable amount of development is in progress or contemplated. The total cost of the controlled water supplies of Malaya amounts to approx. $15,000,000, (U.S.) serving approx. 750,000 persons an av. of 35.7 gal. (Imp.) per cap. daily.—*H. E. Babbitt.*

Report of the Water Analyst, Corporation of Madras, India, for 1937. S. V. GANAPATI. 9 pp. ('38). Tabulations of meteorological data and operating and analytical results are given. Output averaged 23.63 m.g.d. Water supplied, although epidemiologically safe, had slight yellow color and was hazy, due to low depth of sand in filters and operation of units at varying rate. Av. chlorine dosage, applied to filtered water, was 1 p.p.m. Av. no. of bacteria (nutrient agar at 37°, 48 hrs.) in water delivered into distr. system was 318 and 90.8% of samples examined from this source were of 1st class quality, i.e., lactose-fermenting bacteria absent in all quantities examined less than 60 cc. Samples collected from city mains were of poorer quality, indicating deterioration during distr.—*R. E. Thompson.*

Indian Water-works Problems (With Special Reference to the United Provinces of Agra and Oudh). C. W. CASSÉ. Trans. Inst. Water Engrs. **42:** 25 ('37). The Indian consumer is generally uneducated, regards water as free; hence he is apt to waste it. "Standposts" to which the consumer can go for water are common. From 5 to 7 gals. per head per day is the consumption at these standposts. Where there are metered private connections, cons. runs to 20 or 30 gals., and in some cities even higher. Calcutta has av. cons. of 98 gals., and Bombay 77 gals. per head per day. 68.5% of the supply is obtained from rivers at a cost of approx. 5¢ per thousand gals., 21.8% from canals at cost of 6¢, 6.85% from wells at cost of about 10¢ and 2.85% from springs at cost of nearly 20¢ per thousand gals. The water of wells and springs

is harder than the surface waters. Purification plants usually consist of settling tanks followed by slow sand or rapid gravity filters. Double filtration is in operation at Cawnpore. Cl is used for sterilization. Conditions are improving.—*C. A.*

Joint Water Supply Undertakings in Italy. EDITORIAL. Ann. Lavori Pub. (Rome) **77:** 518, 519, and 525, (May '39). Descriptions, with maps and views, of three recently completed installations. (1) Aielli, Cerchio, and Collarmele; rural supply for four villages in rugged, mountainous district, with combined pop. of about 6000. Total length of supply mains, 13.5 km.; of distribution systems, 4 km. Source, mountain springs. Cost, l. 1,650,000. (2) Arce and Roccadarce. Arce is a small town, Roccadarce, a village about 1 km. distant but at 150 m. greater elevation. Water must be brought nearly 3 km. in rough, mountainous district; until this supply inaugurated, much of water used was fetched on mule-back a distance of over 2 km. Source, mountain springs. Cost, l. 1,207,000. (3) Calore. Named after the springs used as source of supply, located in upper valley of Calore River, over which supply is twice carried, in aqueducts, views of which are shown. This undertaking serves 11 communities wholly, and seven others partially, or, in all, about 40,000 pop. Principal main is 72 km. in length and capac. is 50 liters per second. Branch and distribution mains total 38 km. The springs are at el. 1140 meters; the terminal, at Agropoli, is on the Tyrrhenian Sea. This undertaking is the third to be completed of four which will serve the whole Cilento, including 29 communities, and which were approved officially in '32, the government contributing l. 12,000,000 towards the work, or approximately 50% of est. cost. Actual outlay on Calore supply will aggregate about l. 10,000,000.—*Frank Hannan.*

Lock and Canal Planned to Conform with Landscape. FRITZ HAUTUM. Deut. Wasserwirtschaft **34:** 49 (Feb. '39). Desire in Germany to protect water engineering from the reproach of being a blot on the landscape is here exemplified. Problem in this case was to effect junction between navigable river and new navigable canal on outskirts of large, ancient, picturesque, and picturesquely situated city. With a 10-meter drop from canal to river, and only scanty water supply for locking purposes, many difficulties had to be met. Believed that in the result the landscape will have gained, rather than suffered, besides which certain incidental benefits will accrue to the localities affected. Landscape plans of the site as it was before the development and as it will be when development completed are given.—*Frank Hannan.*

WATER TREATMENT—GENERAL

Purification of Water—Trend of Current Practice. GEORGE BAXTER. Surveyor (Br.) **95:** 687 (May 26, '39); Civ. Eng. (Br.) **34:** 203 (Jun. '39). *Paper presented at Summer Meeting of the Inst. of Water Engineers, Edinburgh.* As late as '13 P. A. M. Parker in his work "The Control of Water" stated: "The British semi-official bacteriological standards are: for deep wells no *B. coli* in 10 cc.; for moorland and upland water none in 1 cc." In recent years greater significance is attached to such organisms and the standards

now prohibit their presence in 100 cc. It is considered undesirable to supply any surface water without some treatment, particularly because of the greater accessibility of watersheds. In the absence of any official standard of bacteriological purity the matter rests with the local health officer. A high bacteriological standard is insufficient, however. Consumers will judge water from its appearance and palatability, although there are no British standards for either of these characteristics. Storage for a period of 30 days has been assumed to provide satisfactory bacterial quality, provided no additional contamination occurred during storage. Until comparatively recent years British practice has remained faithful to the system of slow sand filtration. Its disadvantages and limitations are, however, resulting in a trend towards the more or less general adoption of rapid sand filtration. Although general chlorination has been a routine practice for over 20 yrs. and increasingly large numbers of water supplies are adopting it, a considerable prejudice exists against its use, even among water engineers. Ozonization has recently begun to spread from the Continent into England. Where electrical energy can be obtained at reasonable cost, ozonization appears to be preferable to chlorination on several grounds. During past 10 yrs. activated carbon has come into extensive use for removal of tastes and odors. The modern conception of a pure water is tending to become a virtually sterile water, physically pure in the fullest and widest sense. *Discussion.* Surveyor **95**: 717 (Jun. 2, '39). P. B. GLENDINNING (Edinburgh): Stated he was neither an advocate nor an antagonist of universal chlorination but felt it should be used only where necessary, and that it can be avoided by proper design and operation of sand filters. F. A. GIBSON (Grantham W. W. Co.): Pointed out need for a British standard of water quality, which does not now exist. A. A. BARNES (Birmingham): Has adopted the practice of double filtration, i.e. rapid sand filtration followed by slow sand filtration. A. J. MARTIN (Westminster): Called attention to the American practice of sterilizing all newly-laid water mains. B. L. MCMILLAN (Wolverhampton): Felt that standards of quality and dangers of contamination have increased, requiring greater vigilance on the part of the water works authorities. To deal with his water he is employing coagulation with alum followed by sedimentation, rapid sand filtration, and sterilization. F. W. GASKIN (Liverpool): Said that the first bacteriological analysis of water had been made in Liverpool 43 years ago. T. C. GREENFIELD (Douglas, Isle of Man): Pointed out that .1 to .2 p.p.m. of residual chlorine had not been found objectionable in American practice. H. V. OVERFIELD (Scarborough): Recently installed an ozonizing plant to sterilize sea water for a swimming pool. He also disinfects newly-laid water mains with a strong solution of potassium permanganate. T. B. WHITSON: After two years of experience, he feels that ozonization will become future British practice. A. A. FULTON (Dundee): Compared double filtration results in Birmingham and London to show that former is operating at 20,000 gal. (Imp.) per sq. yd. per 24 hr. and the London rate is faster, being 100 gal. per sq. ft. per hour. GEORGE BAXTER: In closing, stated that decision on the extent of water treatment should be in the hands of amalgamated County Councils. He pointed out that sterilization of newly-laid water mains was practiced 5 years ago in Dundee, and has been adopted elsewhere since then.

Although there is no physiological objection to relatively high chlorine residuals there are certainly psychological objections which must be taken into account.—*H. E. Babbitt.*

Water Supply Improvements for the City of Goya. HUGO ALBERTELL. Bol. Obras Sanitarias Nacion (Buenos Aires) **2**: 252 (Sep. '38). A series of infiltration wells located along the margin of one of the shallow branches of the Parana River to intercept the underground flow for the city of Goya's supply, could not be placed in service due to the high CO_2 and iron content of the water obtained. This condition, unexpected in view of the excellent quality of that of the source which feeds the shallow wells, necessitated consideration of a mixed supply of surface and well waters using the latter, after proper treatment, when the former is not available in sufficient quantity. In view of the slight reduction in the 25 to 45 p.p.m. of iron in the water which could be obtained by aeration and sedimentation alone, a treatment plant is being designed with provisions for aeration, lime treatment, mixing, coagulation, sedimentation, rapid sand filtration and chlorination. Basic data for design obtained through laboratory and pilot plant studies. An unusual feature of this plant is its mixing and coagulating chamber. The water, after being dosed with the chemical, will be made to flow by gravity through a narrow channel with sufficient slope to produce velocities between 20 and 40 centimeters per second and of the necessary dimensions and length to allow a 30 min. mixing and coagulating period. This channel arranged in form of a spiral of rectangular plan and therefore consists of a long series of straight runs and right angle bends. This layout will permit efficient utilization of available space, at the same time that it is expected to insure good mixing through turbulent flow generated at the bends. Plant as designed will have the necessary flexibility to treat adequately either the surface or the underground supply.—*J. M. Sanchis.*

Contributions to the Technique of the Treatment of Surface Waters. GERHARD SATTLER. Gas-u. Wasser. **81**: 563, 574, 599 (Jul. 30, Aug. 6, 13, '38). Experience gained in operation of the Königsberg, East Prussia, plant are given. Water is obtained from the river Pregel, on which storage basins are built. An open ditch brings the water to the plant. Sanitary conditions in the storage basin were improved by building small fish ponds on those influents that are polluted. Fish culture and fishing is encouraged in all reservoirs. Large reforestations in the drainage area improved the quality of the surface water. Copper sulfate in amounts of 0.3 to 1.0 p.p.m. is used to eliminate the flagellate *Synura uvella*, and helps also to keep in check the algea *Anabaena* and *Aphanizomenon*. All surface drainage and sewage is kept out of the main ditch by building parallel ditches. Large settling basins have been built at the plant, 17′ deep and holding a 6 day supply, to serve in periods when heavy west winds cause the backing of salt water up the river. Original slow sand filters were partly equipped with rapid pre-filters. Their use doubled the filter-run of the slow sand filters. Winter difficulties with the slow sand filters and the success with the rapid pre-filters caused the construction of full rapid sand filters and abandonment of the slow filters.

Studies of coagulants showed that ferric chloride produced the largest reduction in the oxygen consumed. Addition of potassium permanganate helped in reduction of color. No difficulty encountered in elimination of manganese on the filters by a slow gradual increase of potassium permanganate dosage to 3 p.p.m. Prechlorination and final chlorination is practiced to reduce the bacterial load. Tastes could only be eliminated with activated carbon. Filters with granulated activated carbon had to be abandoned as the water was not sufficiently purified before their use to avoid rapid inactivation of the carbon. Mixing powdered activated carbon into the top 6″ of the sand filter gave good results. Even better results obtained by introducing the carbon into the influent of the coagulation basin. Part of the carbon is inactivated by the floc, but the time of contact for the remaining carbon is greatly increased compared to the use of the carbon in the filters. Apparatus used for uniform dosing of the activated carbon is described. The operation of slow sand filters is discussed in detail, especially the influences of water temperature, pH and coagulating chemicals on the efficiency of the *Schmutzdecke*.—*Max Suter.*

Copper Sulfate in the Water Purification Plant. Paul Weir. W. W. & Sew. **86**: 177 (May '39). Brief but thorough survey of uses of $CuSO_4$ in water treatment. Feeding methods have improved in late years. When $CuSO_4$ is fed alone, these methods are used: (a) porous bag suspension, (b) perforated dispersion box or basket, (c) solution spray, or (d) pulverized crystal blower. When fed continuously, acid resistant solution-feeding equipment is useful. The Atlanta installation feeding saturated solution is described. Quantity of $CuSO_4$ fed is regulated by adjusting flow of water to dissolving chamber. Rate of flow must be adjusted to compensate for varying solubility with varying temperature. A graph for this correction is shown. Dosage ranges from 2 to 10 lbs. per mil. gal., depending on organisms present—the higher organisms requiring higher doses. Purpose of continuous feed is to prevent organism growth. 15 abstracts on $CuSO_4$ use are included, covering algae control, filter bed clogging, copper and health, and uses other than as an algaecide.—*H. E. Hudson, Jr.*

Purifying Water. A.-G. fur Hydrologie. B.P. 487,675; Ill. off. J. Pat. (Lond.) '38, Group I. Water is purified by filtration through dolomite which has been calcined to convert the magnesium carbonate to oxide without decomposing the calcium carbonate. Iron, manganese, chlorine, oxygen, lead and copper are removed from the water and free carbon dioxide is neutralized. The process may be used to remove copper from water to which copper salts have been added for disinfection. Water may be sterilized by filtration through dolomite which has been impregnated with copper or silver salts.—*W. P. R.*

Protection of Pipes by Removing Acids from Water Supplies by Means of Calcined Dolomite. H. A. Haupt. Chemikerztg. **62**: 517 ('38). A granular filter material made from calcined natural dolomite now being used in Germany for removal of acidity from water. Active components are calcium carbonate,

magnesium carbonate and magnesium oxide. Process of particular value in that it removes dissolved iron and manganese from the raw water and retains them in the filter. Hardness of treated water increased by about 0.85° (German) for every 10 mg. of carbon dioxide removed per liter. In waters with high content of carbon dioxide and low carbonate hardness the pH value is raised to about 8.5; the pH value of hard waters remains unchanged. Filtration through these filters reduces the aggressive action of the water to the same extent as lime treatment.—*W. P. R.*

The Elimination of Copper from Water and Sewage. KARL HOLL. Gesundheits-Ing. **62:** 199 (Apr. 8, '39). Copper can be eliminated completely from water by filtering through calcined magnesite. The granulated magnesium oxide is used in a depth of 40". The only service required is occasional backwashing. The precipitated copper can be recovered from the wash water.—*Max Suter.*

Adsorption of Copper Ions by Chlorinated Copperas Floc. C. J. BROCKMAN. Ind. Eng. Chem. **31:** 289 (Mar. '39). Chlorinated copperas, 0.01 *M* in terms of ferrous sulfate, was chlorinated to complete oxidation and 22 to 104 p.p.m. added to phosphate buffered soln. containing 1.9 to 25. p.p.m. of copper. After filtering, pH was from 6.9 to less than 3.8. Above pH 3.8 considerable concentrations of copper ion are completely removed from solution if proper quantity of coagulant is used. Formation of floc does not remove all of the iron from solution at the lower pH values due to solubility of basic ferric chlorides and stability of iron phosphate complexes.—*Selma Gottlieb.*

Removal of Fluorine from Water Supplies. J. C. WYATT. Southwest W. W. J. **20:** 10: 21 (Jan. '39). Proposed plan for softening and fluoride removal from the water for the city of Amarillo, Texas, is to lime soften to take advantage of the magnesium present for fluoride removal, reducing the fluoride from 5 to about 1.5 p.p.m.; recarbonate to original pH and pass through defluorite, and blend this effluent with raw water producing a mixture with less than 6 g.p.g. of hardness and 0.8 p.p.m. of fluoride. Activated alumina and tricalcium phosphate were not satisfactory, the former difficult to regenerate and the latter lost too much material.—*O. M. Smith.*

Consumption of Chemicals for Waterworks Purposes. ANON. Eng. Cont. Rec. **52:** 23: 24 (Jun. 7, '39). Tabulations compiled by Dominion Bureau of Statistics relative to consumption of chemicals in municipal waterworks in Canada during '36 and '37 are given. More than 600 waterworks were circularized and only 206 reported use of chemicals; 88 used chlorine only and 47 others alum and chlorine only. In '37, consumption in tons was: alum 4705, chlorine 624, lime 610, salt 800, soda ash 202, sulfur dioxide 100, chloride of lime 13, activated carbon 24, ammonium sulfate 37, anhydrous ammonia 3. In addition, several municipalities used sodium hypochlorite and several sodium silicate.—*R. E. Thompson.*

Dusting Tendency of Powdered Matter. A. H. M. Andreasen, N. Hofman-Bang and N. H. Rasmussen. Kolloid-Z. **86**: 70 ('39). App. is described for detn. of dusting tendency (d.t.) of powd. substances. It consists of vertical glass tube, inside diam. 43 mm., height 2.5 m., closed on top by iris diaphragm. Equal vols., 2 cc., of powd. are spread over closed diaphragm and covered with dish. When diaphragm is opened, sample falls through tube and is dispersed in air. Tube leads into box, 110 x 75 x 70 mm., which contains 5 sliding horizontal panels; by pushing these into box, rate of settling can be detd. The d.t. is defined as that part of sample, expressed in percentage, which is left suspended in air 6 sec. after start of test. This gives d.t. of 100 to lycopodium and 0 to powd. quartz. Curves representing rate of settling are compared with fineness curves of same substances. It is shown that if finest particles are removed from powd. substances their d.t. is increased, contrary to general belief.—*C. A.*

Selection of Pumps for Chemical Service. Ward E. Pratt. Ind. Eng. Chem. **31**: 408 (Apr. '39). The chemical and allied industries have many and involved pumping problems requiring special pump materials. In handling corrosive or corrosive-abrasive liquids, selection of material is of first importance. Necessary for pump mfgr. to have full information about fluid to be pumped. Reciprocating and rotary pumps present particular difficulties under corrosive conditions because of necessity of close clearances or actual rubbing contact; reciprocating type pump economical where small capacities and high pressure necessary or where it is essential to avoid churning action produced in centrifugal pump. Centrifugal pumps used in about 90% of applications handling corrosive liquids. Self-priming first came into existence to fill demand for pumps which could not be conveniently located with flooded suction, other advantages that became apparent were less stuffing box leakage trouble and production of usable vacuum, on filters for example. Author urges giving pump mfgr. full information of pumping problem and cites several examples where more complete data would have saved much operating difficulty.—*Martin E. Flentje.*

SEDIMENTATION AND COAGULATION

Sedimentation in Theory and Practice. Anthony Anable. Eng. Cont. Rec. **52**: 14: 13 (Apr. 5, '39). Particles in suspension tend to move downward at velocity depending upon their size, wt., and shape and upon viscosity of suspending medium. Spherical particles settle more rapidly than irregular ones of same sp. gr. Liquid clears first and most rapidly at top, coarsest and heaviest particles going down first, followed successively by finer and finer particles. If theoretical detention period could be attained in practice and if velocity and distribution of flow and take-off had no appreciable effect, there would be no choice between 3 possible tank shapes, square, rectangular and circular. For max. effectiveness, weir and overflow trough should be of max. possible length and located as far as possible from point of feed. Circular and square tanks with central, sub-surface feed and peripheral overflow are ideal from feeding and distribution standpoint. Head of water above feed ports

exerts dampening effect that irons out irregularities. At normal rates of flow, annular ring of flocs may be observed several ft. out from central feed distributor. This annular ring contracts and expands as rate varies, showing that uniform distribution is obtained at all rates of feed. With rectangular tanks of appreciable width it is difficult to effect immediate fanning out of influent across entire cross section. Baffles are used for this purpose and are quite effective for certain definite rate of flow. Change in flow rate, however, brings into play totally different set of hydraulic conditions and short circuiting usually results. In circular or square tank av. rate of radial propagation is same as constant rate of propagation in rectangular tank. In former, rate starts at max. and is reduced finally at point of overflow to min. far below constant rate prevailing in rectangular unit (of same theoretical detention period). Advantages of continuous sludge removal include possibility of returning portion of sludge to influent to aid coagulation and constant rate of discharge of sludge to streams or other bodies of water, which is less objectionable than intermittent sluicing of tanks.—*R. E. Thompson.*

Steel Pickling Liquor as Coagulant. J. A. GETTRUST AND C. O. HOSTETTLER. Ann. Rept. Ohio Conf. Water Purif. **18:** 47 ('38); W. W. Eng. **92:** 245 (Mar. 1, '39). Water supply for Akron, Ohio, treated with alum as only coagulant from '15 to '35, since then Fe salts in pickling liquor from near-by mfg. plant used with or without alum. Liquor transported to water plant in 850 gal. truck mounted steel tank, non acid proofed. Has life of approx. 6 mo. daily use. Chemical stored until needed in 10,400 gal. wood tank, fed by gravity to 2 orifice boxes in plant. Iron used either with lime or as chlorinated copperas. Liquor weighs approx. 10 lbs. per gal. containing from 1 to 4 lbs. $FeSO_4 \cdot 7H_2O$, and 1% free sulfuric acid. Theoretically 1 lb. of chlorine req'd. per 7.8 lbs. ferrous sulfate, in practice ratio 1:7.2 used. Lime and iron used for colors in water less than 40 p.p.m. and alk. greater than 50, iron added first then lime to pH 8.6–8.9. On higher colors this process unsatisfactory, then iron soln. chlorinated. Sometimes alum used with chlorinated copperas, effective ratio of iron to alum varies with water temp. Comparative costs at Akron (emphasized for Akron only) if assumed to be $1.00 for iron and lime, are for chlorinated copperas, $1.40 and for alum $1.85.—*Martin E. Flentje.*

The Possibility of Using Italian Bentonite for the Clarification of Water. L. GABBANO. Igiene mod. **31:** 97 and 156 ('38). *Part 1. The effect of the electrolytes on the flocculation and sedimentation of suspensions of bentonite.* Comparative experiments with an American preparation of bentonite ("Acquagell") and an Italian bentonite showed that the Italian bentonite in its crude state was not an effective coagulant but acquired the necessary properties after simple treatment which increased its colloidal properties. Experiments showed that with the electrolytes generally present in water the minimum quantities which must be present before flocculation can occur in a short time were 1 milliequivalent per liter of bi- and trivalent salts and 50 of monovalent salts. Author gives the time necessary for formation of floc, volume of floc formed, and rate of sedimentation for different salts at various concentrations. Above a certain minimum concentration (generally 10 milliequivalents

per liter) flocculation and sedimentation take place the same extent with alkalis as with acids. Finally it is concluded that, with addition to water of 0.01–1 gram of bentonite per liter, precipitation will take place within about 1 hr. provided that there is present a minimum quantity of salts corresponding to a solid residue at 100°C. of 0.07–0.10 gram per liter. Natural waters are not likely to contain less than this minimum and precipitation can in practice be obtained in all cases. *Part 2. Experiments on waters of varying degrees of turbidity.* Describes results obtained in experiments on clarification with bentonite and aluminum sulfate of numerous natural waters of various degrees of turbidity. No water was found with a content of salts so low that precipitation would not take place with bentonite. In all cases clarification was accomplished in less than 6 hrs. with quantities of bentonite considerably less than the quantities of aluminum sulfate required. In water treated with bentonite no floc remained in suspension while with aluminum sulfate, using quantities greater than the necessary minimum and the usual settling time of 6 hrs., some floc always remained in suspension. After treatment with bentonite the water could be filtered at a higher rate and filter runs were longer. Removal of added color was better with bentonite. Bentonite does not add carbon dioxide or aluminum to the water and does not increase its hardness. The results obtained with bentonite and the fact that it costs slightly less than aluminum sulfate indicate that it should be preferred as a coagulant for turbid water destined for potable use and for swimming ponds with recirculation systems.—*W. P. R.*

Effect of Bentonite upon the Caking of Iron Sulfate. CLARENCE BAHLMAN AND E. B. EVANS. Ann. Rept. Ohio Conf. Water Purif. **18:** 98 ('38). Bentonite, natural hydrous aluminum silicate which swells reversibly in water to at least 6 times its original volume, may be used for coagulation of water. Flocculation, which is much more voluminous than with equivalent amount of alum, is effected by ionizable salts and if water is deficient in this regard another coagulant must be used with bentonite. It may also be employed to reduce caking of chemicals used in water purification. Ferrous sulfate causes difficulties due to caking and lab. tests were conducted to determine effect of admixtures of 1, 3 and 5% of bentonite (Volclay). Marked inhibitory effect on caking was observed. Uniform mixing of clay with chemical and preventing segregation might be difficult.—*R. E. Thompson.*

The Fundamental Chemistry of Alum and Its Application to Paper Manufacture. LEWIS B. MILLER. Paper Trade J. **108:** 2: 34 ('39). Some of less well-known aspects of fundamental chemistry of alum are discussed, particularly the reactions of alum in dil. solns., such as used in paper manuf., and factors affecting alum floc formation.—*C. A.*

USE OF SODIUM SILICATE

Experiments at Toledo with Sodium Silicate. R. W. FURMAN. Ann. Rept. Ohio Conf. Water Purif. **18:** 109 ('38). Lab. tests with alum and sodium silicate indicated that improved flocculation could be obtained at cost about

equal to that with alum alone. Addition of lime prior to silicate hastened floc formation and increased size of floc. Pronounced improvement was observed when silicate was used with alum at temps. below 45°F., when coagulation with alum, either alone or with lime, is very slow, although floc was smaller and formed more slowly than at higher temps.—*R. E. Thompson.*

Experiments Using Sodium Silicate and Aluminum Sulfate at the Water Purification Plant at Lima (Ohio). E. E. SMITH. Ann. Rept. Ohio Conf. Water Purif. **18:** 108 ('38). At least 2 g.p.g. of alum is required for coagulation at Lima. Lab. experiments showed that 0.25 g.p.g. alum and 0.75 g.p.g. sodium silicate produced floc superior to that obtained with 2 g.p.g. alum. Plant scale trials will be conducted.–*R. E. Thompson.*

The Use of Sodium Silicate in the Coagulation of the Water Supplied to the City of Cordoba (Argentina). CARLOS E. GIETZ. Bol. Obras Sanitarias Nacion (Buenos Aires) **3:** 263 (Mar. '39). The purification of water from Primero River presented an unusual problem because of the difficulty with which its relatively low turbidity, caused chiefly by suspended organic matter, could be coagulated. Preliminary experiments have shown that treatment with sodium silicate prior to the addition of $Al_2(SO_4)_3$ resulted in a much faster formation of floc, an increase in sedimentation velocity, a greater resistance to breaking of coagulum, a faster rebuilding of floc when dispersed by violent agitation, and a decanted water of better quality. Comparable clarification was obtained with an alum dose of 100 p.p.m. without silicate treatment and with a 20 p.p.m. silica dose followed by the addition of 50 p.p.m. of alum. A more extensive investigation of the suitability of sodium silicate as an aid to coagulation, is now being planned.—*J. M. Sanchis.*

Summary of Experimental Work at Lawrence Experiment Station for the Year 1938. ANON. Massachusetts Dept. Pub. Hlth., Div. San. Eng., News Letter (Mar. '39). "Comparative studies on rapid sand filtration of Merrimack River water showed that the use of sodium silicate with alum to improve the floc resulted in insufficient improvement, over the satisfactory floc obtained with alum alone, to warrant its continued use. Prechlorination of the water when applied to such filters was found to reduce the coli-aerogenes organisms in the filter effluent, but it was not necessary. The small number of coli-aerogenes in the effluent without the use of prechlorination were taken care of by post chlorination."

Effect of Silicate Treatment on Quality of Water. JOHN R. BAYLIS. W. W. and Sew. **85:** 855 (Sep. '38). Redescribes cotton plug filter unit for measuring effluent turbidities, and discusses procedure and technique in using it. Results from 5 filters over a 6 mo. period are given. Sand size ranged from 0.6 mm. in one filter to 1.5 mm. in another. Superiority of filtered water when silicate treatment is used is clearly demonstrated, particularly during periods of weak coagulation.—*H. E. Hudson, Jr.*

FILTRATION

Tests for (Filter) Sand and Gravel. C. M. TIEMERSMA-WICHERS AND E. JACOBS. Water (Neth.) **75:** 99 (May 5, 19, '39). *A revision and extension of paper by same authors in J. A. W. W. A.* **24:** 705 (May '32). The surface of the sand grains affects the physical, chemical and biological processes of the filter. The sand grains' surface indicates the number of points where grains touch, the average voids and the relation between surface and voids. The percentage voids in relation to volume unit is unimportant for filter material; this figure does not differ greatly for different sand. To determine the practical use of the method a number of different sand and gravel samples obtained from water plants and natural sands were tested. The surface of packed sand (S), the voids (V), the effective size (ES) and the uniformity coefficient (UC) were recorded.

Characteristics of sand and gravel

NATURAL SAND	S SQ. METERS PER CC.	V CU. MM. PER 1000 SAND GRAINS	ES MM.	UC
Moor sand	301.013	0.285	0.063	2.532
Soft sand	263.375	0.403	0.071	2.278
Dune sand (filters)	188.611	1.563	0.126	1.875
River sand	112.140	7.715	0.231	1.659
Sharp building sand	96.855	9.779	0.254	1.819
Yssel pearl sand (filters)	75.874	19.749	0.332	2.029
Yssel pearl sand (filters)	74.082	19.351	0.320	2.253
Gravel sand (coarse)	66.102	5.367	0.310	3.789
Gravel sand (filters)	22.402	70.480	0.6000	5.716
SIFTED SAND OR GRAVEL				
Sand (iron removal filters)	51.554	109.367	0.544	1.479
Sand (iron removal filters)	35.818	234.202	0.635	2.180
Sand between filters	28.326	200.296	1.039	1.546
Gravel (final softening filter)	26.177	714.654	1.046	1.507
Gravel pre-filters	13.912	1,318.278	2.052	1.527
Gravel pre filters (softening)	10.689	11,530.245	2.279	1.669
Gravel (rapid filters)	5.512	86,527.157	6.041	1.184
Gravel (iron removal pre-filter)	5.405	86,092.715	6.072	1.183

The groups are given in descending order of S. Plotting the results show that S and V have specific characters. The graphs indicate that Allen Hazen by choosing "effective size" instinctively took a good measuring stick, because the ES curve has the same slope as curve V, which characterizes the size of voids, but the ES curve is much less pronounced than the V curve, is less sharp and is less characteristic. The UC curve shows little. Comparison of the figures for S and V of the different sands and gravels indicates that by

sifting, the size of voids (channels) can be appreciably enlarged without reducing the surface of the grains per cc. The improvement attempted by sifting is clearly shown by determination of S and V. The fine fractions have considerable influence on S and V. The principle crudely shown by Hazen's "effective size" is shown more rational and clearer by determination of S and V. Determination of S and V has been perfected for filter material, but is feasible for characterizing sand and soil in general, as long as the material is crystalline in nature. Soil containing clay or humus must be washed before drying. The apparatus used is shown by drawings and photographs. The "Ro-tap" test sieve shaker is commercially available, the apparatus for determining voids in wet sand is made in accordance to plans. In general, filtration is most effective when grain surface per cubic unit is large, and channels are small, or a low figure for voids per 1000 sand grains. Rapid increase in head is related to these factors, but in opposite direction. The fitness of the sand to be cleaned by back washing is typified by the figures, but requirements are more or less opposite to those for good filtration. It is, therefore, necessary to choose between the various possible surfaces and voids, when various water qualities, filter rates, types of treatment, etc. are required. The figures for S are in close relation to filter practice; the figures for V are based on the same principle as S, but are farther removed from actual conditions.—*Willem Rudolfs.*

New Jersey—Birthplace of the Filter. M. N. BAKER. Eng. News-Rec. **122: 777** (Jun. 8, '39). Interesting details given of early history of mechanical filtration. In crude way, filter took form at Rahway under hand of Patrick Clark. Adapted and improved by John Wesley Hyatt, it assumed new form at Somerville and later was combined with coagulation process of Isaiah Smith Hyatt. With further changes it was installed at Long Branch. All this occurred in decade ending 1888. Radically different rapid filter plant was designed by George W. Fuller, 14 yrs. later, for Little Falls. Clark filter had sand depth of only 3-6″, supported on wire cloth. Unable to cope with muddy Mississippi R. water for industrial plant, I. S. Hyatt adopted suggestion of L. H. Gardner, supt. of New Orleans Water Works Co., who had been experimenting with sedimentation aided by perchloride of iron, and applied for patent on coagulation combined with filtration in 1883. Coagulant was applied as water entered filter. Pre-aeration and sand agitation (during washing) were introduced by the Hyatts at Long Branch in 1888. Aeration was effected by discharging water down 16″ pipe divided by vertical partition and sunk 100′ into ground. Raw water fell down one side of partition, sucking in air, and rose up on other side to pump well, alum being applied to water on its way to filters. Filtering medium was "prepared coke" and sand, in ratio of 3:1. Aeration by other means later became feature of iron removal plants, first of these in America being completed at Atlantic Highlands, N. J., in 1893. Mechanical filters multiplied rapidly after 1887 and were subjected to much experimentation, most notable being experiments of Fuller at Louisville, published in 1898, results being embodied in Little Falls, N. J., plant in '02. In this plant, rectangular tanks and, most revolutionary, pre-coagulation instead of instantaneous coagulation were employed.—*R. E. Thompson.*

Twin Rapid-Sand Filtration Plants Serve Danbury, Conn. ANON. Am. City **53:** 12: 35 (Dec. '38). The process industries of Danbury consume 70% of the 6 m.g.d. total demand of the city. Hence their needs for water with a pH of 7 to 7.5°with no phenolphthalein alkalinity are of primary importance. The system here now consists of 2 major parts, namely, the older West Lake reservoir fed by 2 smaller ones and the Marjorie reservoir likewise fed by 2 smaller ones. West Lake water has a color of 20 to 25 and an alkalinity of 12 while that from Marjorie reservoir has a color of 40–50 and an alkalinity of 26. West Lake water is more corrosive than that of Marjorie Lake. There are filtration plants on each of the 2 lakes which are identical except that the West Lake plant has no flocculators. Raw water flows to an aerator, receiving alum on the way, which reduces carbon dioxide and saves considerable lime later in the process. From the aerator water passes thru a turbo-mix, flocculator compartments and into a coagulating basin with around-the-end baffles and detention of 7 hrs. Neither the turbo-mix nor flocculators are now needed as adequate floc is formed without them. Six rapid sand filters operate as one and to cut out any one filter all must be shut down. Water then passes to a ½ mil. gal. clear well. Lime is applied between the filters and clear well and post-chlorination when needed. Pre-chlorination is preferred as it results in chemical savings. Ammoniation apparatus is provided and carbon can also be applied. In Jan. '39 sodium silicate was substituted for lime to improve the character of the water for industrial use.—*Arthur P. Miller.*

The New Filter Plant of the St. Louis County Water Co. W. V. WEIR. W. W. and Sew. **85:** 1023 (Nov. '38). Plant is supported on piles. To the existing mixing and settling units were added low lift pumping station, secondary flocculation, and 8–4½ m.g.d. filters which operate at 3 g.p.m. per sq. ft. Wheeler bottoms used. High wash rate provided. Details given. High filtration rate has proven satisfactory. Filters washed according to effluent turbidity. Mud ball tests have been made repeatedly. Manual hose scour is used prior to each wash. Design and operating statistics included.—*H. E. Hudson, Jr.*

Utilities for a Vast Industrial Plant. ANON. Eng. News-Rec. **121:** 783 (Dec. 22, '38). Water supply system of new Irvin Works of U. S. Steel Corp., utilizing Monongahela R. as source, is described. Water from river will be pumped through 42″ steel main from elev. 718 to 3.74-mil. gal. circular steel reservoir at elev. 1100. Lime introduced prior to pumping to minimize corrosion, feeders being controlled by pH meter. A 6-m.g.d. all-steel Morse filter plant, consisting of 2 mixing chambers, 2 sedimentation basins, 4 filters and wash water tank, was provided for treating part of supply. Filters will operate at rate of 3 gals. per sq. ft. per min.—*R. E. Thompson.*

Filter Stoppage by Microörganisms. KENNETH WALDECK. Proc. 11th Ann. Conf. Water Purif. in West Va. Univ. Eng. Expt. Sta., Tech. Bull. **9:** 14 ('37). Presence of *Synedra* in the raw water was found to be cause of filter stoppage. Neither backwashing of the filters, scraping of the filter surface, nor use of copper sulfate proved of any value. By increasing alum dosage from 0.5 to 1.5 g.p.g. in one plant and from 1.3 to 5.0 g.p.g. in another plant the

trouble was removed. As result of the heavier floc produced by the increased alum dosage the microörganisms were removed in the sedimentation basin. —*C. A.*

Biological Researches into the Effects of Sludge Stirred Up by Floods in Rivers. R. KOLKWITZ. Kleine Mitt. Ver. Wasser-, Boden- u. Lufthyg., **14:** 24 ('38). Survey of causes of difficulties experienced at water works in Germany in Jan. '38. Mild weather and large discharges from beet sugar factories in autumn of '37 caused vigorous growth of *Sphaerotilus* in the streams, and sudden floods in Jan. '38, cleared the banks and beds of the rivers of fungus, sand, etc. Amount of suspended matter carried by river waters was very great, reaching a maximum of 40 cc. per liter. This material formed a thick layer on sand filters and led to considerable trouble in operation. To avoid this trouble, settling ponds or tanks might be used before the filters. *Sphaerotilus*, however, settles with difficulty, and if carried down by the slime in the water may decompose slowly and be dispersed through the water again by gas bubbles. Other possibilities are screening, increase of filter area, insertion of coarse preliminary filters, or addition of a layer of anthracite on the surface of the sand filter to act as a mechanical filter and prevent formation of a continuous mat.—*W. P. R.*

Filter Bed Agitation with a "Filter Sweep." C. E. PALMER. W. W. and Sew. **85:** 956 (Oct. '38). High velocity wash did not keep Erie, Pa., filters clean. A surface wash system involving a rotating manifold propelled by the discharge through jets is described. Two months application in a dirty filter made the sand entirely clean. 10 of 16 Erie filters were equipped with "filter sweeps" and results were satisfactory. Sweep can be used for "bumping" filters. Results with anthrafilt were excellent. The sweep worked well with combination sand and coal beds.—*H. E. Hudson, Jr.*

Results of Filter Cleaning with Sulfur Dioxide at Wheeling, W. Va. A. R. TODD. Taste and Odor Control J. **5:** 3: 1 (Nov. '38). After 10 yrs. of service the sand in the Wheeling filters had to be replaced; however, gravel and underdrains were not disturbed. After about 4 more years of service this new sand also turned black from manganese; this was not objectionable but the underdrains were becoming stopped up. Samples of filter sand were successfully cleaned by a 3% and 4% solution of sulfur dioxide. It was then decided to try this method out on a filter bed to determine its effectiveness on the underdrains. A filter of 2,000,000 gallons capacity was treated with 2,550 lbs. of sulfur dioxide gas. The water containing this gas was circulated through the filter for 12 hrs. Filter was washed 7 times and allowed to operate normally through the rewash valve and at the end of 12 hrs. it was turning out good clear non-acid water. The treated filter now uses 72,000 gal. of wash water in 5 min., as compared with 55,000 gal. before treatment, and has increased its runs about 30%. This treatment cost only 10% to 12% of the cost of rebuilding the filter. Author believes that better results would be obtained by giving the filters a 2% treatment every second year instead of waiting 8 or 10 years and then attempting to clean them in one treatment.—*P. H. E. A.*

Cleaning Filter Beds with Sulphur Dioxide. B. A. Poole. Pub. Wks. **69:** 10: 12 (Oct. '38). Report of SO_2 treatment of an incrusted filter sand in which sand size increased from 0.40 mm. to 0.55 mm. within 3 yrs. First 2 applications unsuccessful due to clogged underdrains, after repair 5% solution and 18 hrs. recirculation cleaned the sand.—*Martin E. Flentje.*

BOILER FEED WATER TREATMENT

Purification of Water for Boiler Feed Purposes. Frederick G. Straub. J. Franklin Inst. **227:** 591 (May '39). Past two decades have seen great increases in boiler pressures, temperatures and capacities. Thermal efficiencies have increased from 7.51 to 17.35% as a result of increased stream pressures and temperatures, rate of heat transfer, size of units and improved methods of combustion. These advances have rendered imperative the proper conditioning of the boiler feed water. Although treatment of feedwater is a complex problem, a few general principles have been evolved which serve as guides in determining the proper treatment. Total solids in boiler water should be maintained as low as possible. When operating conditions necessitate a relatively high solids content, washing the steam with boiler feedwater will maintain the solids in the steam at a low value. Degasification by either mechanical means with particular reference to the removal of oxygen is a necessary process. Adjustment of pH offers an effective method of minimizing corrosion. External treatment of the boiler feedwater with coagulating and softening chemicals is frequently advisable in order to reduce the amount of scale-forming solids. Internal treatment of the boiler water to maintain scale-forming solids in the soluble state or to precipitate them as a non-adherent sludge is widely practiced. The phenomena of embrittlement in steam boilers has been extensively studied and chemical treatment methods have been proposed. These have involved the maintenance of definite amounts of sulfates and chlorides in the lower pressure boilers and reducing the silica content in the higher pressure installations. Likewise, improved methods of constructing boilers have decreased the tendency towards embrittlement. The author describes three typical modern boiler installations in central stations and in industrial plant.—*Sheppard T. Powell.*

Water Conditioning in Steam Generation. Everett P. Partridge and A. C. Purdy. Ind. Eng. Chem. **31:** 387 (Apr. '39). In last 20 yrs., max. boiler pressures have increased from 350 to 2500 lbs. per sq. in., evaporation rates per boiler from 150,000 to 1,000,000 lbs. per hr., and total steam temp. from 660 to 950°F., all made possible by advances in boiler design and construction and in water conditioning and control. Improvements in boilers include water cooled furnace walls, molten slag removal of ash, steam washers, installation of a few large boilers instead of many small ones, and forged drums and welding instead of riveting. More boilers are now operated by technically trained men. Higher boiler ratings demand better water conditioning. For scale prevention, external softening is reinforced by addition of ortho- or metaphosphate to feed water. Sodium aluminum silicate scale is controlled by elimination of aluminum and silica from feed waters. For corrosion pre-

vention, dissolved oxygen is reduced as low as 0.005 p.p.m. with sodium sulfite. "Caustic embrittlement" problem has been confused by recent discovery that pure sodium hydroxide is not cause of intergranular cracking, and that sodium sulfate has little preventive effect. Silica is now thought to be cause and R_2O_3: SiO_2 ratio of 0.6 apparently protects. Carry-over is caused by both inorganic and organic substances; feed water treatment is best solution, since no material is known which is sufficiently effective anti-foam agent when added to boiler. Water conditioning is controlled by more exact analytical methods than previously. Many troubles can be avoided in new installations by proper boiler design, foregoing present economies for future savings through improved performance.—*Selma Gottlieb.*

Deaerators and Their Applications. E. S. DAUGHERTY AND C. E. JOOS. Combustion **10:** 8: 31 (Feb. '39). A brief outline of the theory of deaeration is given and followed by a short description of the three basic methods, namely: reboiling, flowing over trays or pans, and atomizing. In the reboiler oxygen is removed by passing steam through the water. The possibility of water hammer, most dangerous on starting, has hindered the adoption of this type in the U. S. The tray type is widely used because of its simplicity and low cost. A counterflow and two parallel flow types are described. The atomizer method consists of spraying water into a steam atmosphere to remove 95% of the D. O. and forcing this heated water through a jet dispersing it to a mist permitting ready loss of the remaining gases. The atomizer type is suitable to water of low pH and containing suspended matter since few parts need be of non-corrosive material. Deaerators have their application in boiler feedwater treatment, in hot water systems for large buildings, in cooling water for iron or steel heat exchangers, or where corrosive water is to be delivered many miles from its source. Chemical deaeration with sodium sulfite or ferrous hydroxide becomes costly when the oxygen to be removed approaches 2 or 3 cc. per liter.—*T. E. Larson.*

The Recirculation of Boiler Salines. S. M. SPERRY. Combustion **10:** 12: 27 (Jun. '39). Corrosive action on steel-tube economizers and boiler-feed pumps can be hindered by raising the pH of the boiler feedwater to 8.6–9.0 and increasing the sulfite concentration by recirculating a few per cent of the boiler water. This method of correction eliminates or reduces the quantity of chemicals which would otherwise be necessary and does not result in a rapid concentration of alkaline material in the boiler, thereby having no effect on normal blow down conditions. Each station must be considered as an individual problem when recirculation is proposed. A careful review is necessary of the whole cycle involved, including the possible effect on the functioning of each piece of equipment and on the station heat balance.—*T. E. Larson.*

Value of Water Treatment. W. L. CURTISS. Bul. Am. Ry. Eng. Assn. **40:** 407: 227 (Dec. '38). Detailed comparison of the water quality on different districts of the New York Central R. R. with costs for boiler repairs and fuel consumption in the respective territories during '23–'24, developed an annual

loss of $3,117,627, caused by use of bad water. This loss slightly exceeded the estimate based on the Am. R. Eng. Ass'n. formula of 13¢ per pound of incrusting solids going to the boilers. Use of automatic blowdown has permitted extension of washout period to 30-day Federal limit with further saving.—*R. C. Bardwell.*

Methods for Checking and Handling the Control of Locomotive Blowdowns. J. B. WESLEY ET AL. Bul. Am. Ry. Eng. Assn. **40**: 407: 243 (Dec. '38). Water chemist must first determine the critical concentration at which foaming may be expected for various types of power and service for respective districts. Care required in taking samples to avoid flash loss and standardizing checks should be gravimetric determinations. For routine check and control, both delicate hydrometers and electric conductivity measuring instruments which have been calibrated against solutions typical of the respective districts, are being used to advantage. Suitable blowdown facilities must be provided at terminals and also on locomotives for handling on line of road and the amount of blowing must be carried out in accordance with instructions developed from the concentration pick-up tests.—*R. C. Bardwell.*

Determination of the Density of Boiler Waters. WESLY. Wärme **61**: 75 ('38). Discusses methods for determining the "density number" of boiler water, i.e., the concentration of a material in the boiler water divided by the concentration of the same material in the feed water. Determinations of the density of boiler water with a Baumé hydrometer are not sufficient, as differences in concentration of salts, which are great enough to affect the operation of the boiler, cannot be determined by the hydrometer. A convenient method of determining the density number is to find the ratio of chlorides in the boiler water to that in the feed water.—*W. P. R.*

Supervision of Boiler Feed Water with the Aid of Lime-Soda Diagrams. I. ARBATSKY. Vom Wasser **13**: 212 ('38). The water-diagram method makes it possible to solve, by geometrical means, difficult problems in connection with the preparation of boiler feed water and water softening. An attempt is made to show how control is possible without chemically trained personnel, adapted for engineers.—*Willem Rudolfs.*